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THE RELATION OF ADAPTABILITY TO ADAPTATION

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THIS article is the first in a series of essays on the ecological aspects of some problems of the origin of species. Its chief purpose is to summarize the results of my recent experimental investigations on the relation of adaptability to adaptation in unicellular organisms, which were published in the Russian language in various biological journals of U.S.S.R., and to coördinate the results thus gained with the rest of our knowledge in that direction.

The study of the mechanism of the adaptive process is essentially an ecological problem. When a population of a given species is subject to the action of altered environmental conditions, for example, the increased concentration of salts or of some other chemical substances in the medium of an aquatic animal, a number of complicated processes sets into operation. On the one hand, there exist inherent initial differences in susceptibility to the new conditions among members of a given population of individuals. Further, there exist inherent differences in adaptability of different individuals to the altered environmental situation. Adaptability is here used as the capacity for adaptive modification in individual development, which is due to a number of physiological mechanisms acquired in the previous history of a given species.

What will be the effect of natural selection under all these circumstances? Will it favor an outstanding initial strength, or an extremely rapid adaptability, or both of these? What will be the results of selection in the populations of the various species and under different factors of the environment?

It will be useful to consider separately two different possible situations: First, the mechanism of the adaptive process to the environment which is gradually changing. It is this problem of changing environment which is only considered in the present article. Experimental work along this line has led to the discovery of the peculiar relation of adaptability to adaptation within the population of one and the same species. It has also shown the importance of the magnitude of genetic diversity in adaptability of different individuals in a population, as compared to the magnitude of diversity of the same individuals in their inherent initial strength.

Second, it will be appropriate to treat the case when some environmental factor has changed from one to another of relatively fixed values. How will natural selection work to stabilize the population under the new steady circumstances? The consideration of this problem is reserved for subsequent publication.

THE IMPORTANCE OF ADAPTIVE MODIFICATIONS FOR EVOLUTION

The part played by adaptive modification in evolution has been much less than adequately valued in the recent development of biological thought. As Pearl (1939) truly remarked, this is an obvious consequence of the trend given to biological philosophy by Weismann and Bateson, with their emphasis upon the entailed or endowed element in the whole biological picture.

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It is well known that all organisms have the capability to alter themselves to meet the fleeting changes in their circumstances. Various adaptive modifications acquired under the effect of environment are not hereditary, but the very feature of adaptability is undoubtedly an outcome of the long historic process of natural selection. Adaptability is useful, and natural selection has provided for that specific architecture of physiological processes that guarantees the production of appropriate modifications. Whether or not all modifications are actually adaptive is a problem in itself, and this subject will be given due consideration in one of the subsequent articles.

Since adaptive modifications are not hereditary, they are usually believed to be of no importance for evolution processes. However, there are also advocates of a different attitude. The reasoning of Lukin (1936) is as follows. Adaptations of organisms to environment are of two kinds: First, non-hereditary alterations under the effect of environment upon physiological systems of the developing organism. For example, animals grown in low temperatures are larger. This is useful for temperature regulation in a cold climate, because of the decrease of surface per unit of body volume. Second, a similar gain in body size can be brought about by chance mutation, without any action of low temperature.

This parallelism of hereditary and non-hereditary variations is rather widely spread and it can be satisfactorily explained by developmental physiology. In both cases the alteration of an organism is usually due to a change in the relation between rates of some biochemical reactions. Whether this relation is shifted because of the altered temperature conditions, or because of variation in quantity or quality of catalyzers, in its turn depending on mutation in the hereditary material, the effect of both these different causes is the same. Sometimes it is stated that non-hereditary modifications duplicate hereditary ones. The former are then called "phenocopies" (Goldschmidt, 1938). Sometimes the terminology is reversed and mutations are called "genocopies" of non-hereditary modifications (Schmalhausen, 1938).

Are there some reasons to suspect genocopies to be in some respects particularly useful in the mechanism of the adaptive process? Lukin (1936) recently pointed out that there are at least two reasons for such a belief. On the one hand, a casual genocopy can be suspected to be summed up with the useful phenotypic modification, and consequently produces a particularly vigorous organism in some specific respect. This is the principle of intensification of characters. On the other hand, some useful feature of organization by the way of genocopy is developed relatively independently of the accidental interplay of environmental factors at the time of ontogenesis, and in this respect it might be advantageous over the common adaptive modification. This is the principle of autonomization of characters. In other terms, according to this conception, natural selection will favor distribution in populations of genocopies augmenting and improving the external expression of adaptive modifications. If after such a selection a population returns to the original conditions of its existence, the former adaptive modifications appear to become hereditary. This is one of the central points of the whole theory, which should consequently be called a hypothesis of hereditary fixation of adaptive modifications by means of natural selection of genocopies. In the light of this conception adaptive modifications prepare the way for the subsequent evolutionary advance.

THE MAGNITUDE OF ADAPTIVE CHARACTER

The theory outlined above evidently operates with the concept of magnitude of adaptive characters. This magnitude means the value of those features or characters which are useful, and which determine the survival of an individual in the process of natural selection. It is admitted that the greater is the magnitude of some adaptations, the more are the advantages associated with the possession of them.

Let us take for example the case of adaptation of an aquatic animal to the increased salinity of the medium. It will be seen that a part of total adaptation, i.e. of total resistance to salinity observed under the new environmental conditions, will form a feature of organization deeply rooted in the previous history of a given species. We mean the original resistance to salinity in the initial conditions, which would be maintained if the environmental conditions remained unaltered. It is this initial inherent adaptation which can be augmented or weakened by means of genocopies.

The other part of total adaptation observed under new environmental conditions represents adaptive modification. It is the outcome of onto-

genic adaptability, the adaptive response of the organism to the altered conditions of its existence. This second part of total adaptation is in its turn subject to hereditary alterations.

Summarizing, it can be stated that the total magnitude of adaptation in the case of some adaptive characters (but certainly not in all of them) can consist of two components: initial adaptation and acquired adaptation. Hence:

$$\left\{\begin{array}{l}\text{The magnitude}\\ \text{of adaptive}\\ \text{character}\end{array}\right\} = \left\{\begin{array}{l}\text{Initial adaptation before}\\ \text{the beginning of action}\\ \text{of a specific environmen-}\\ \text{tal change. Depends upon}\\ \text{previous history of a given}\\ \text{group of individuals}\end{array}\right\}$$

$$+ \left\{\begin{array}{l}\text{Adaptive modifi-}\\ \text{cation acquired}\\ \text{under the action}\\ \text{of the specific}\\ \text{environmental}\\ \text{change}\end{array}\right\}$$

The theory outlined above can now be formulated thus. A casual increase of initial adaptation by means of genotypic alteration must be summed up with the magnitude of adaptive modification, and consequently yield a larger value of total adaptation useful for an organism. It is only with such summation of adaptations that natural selection could augment adaptive modifications by genocopies resembling them.

THE CONSTANCY OF TOTAL ADAPTATION IN SOME ADAPTIVE CHARACTERS

We have now sufficiently clarified some basic concepts underlying the theory of hereditary fixation of adaptive modifications by means of natural selection of genocopies, and we can now attempt to prove this theory by direct experiments. Is the genotypic increase of initial adaptation really summed up with the magnitude of adaptive modification?

This problem was analyzed for the case of adaptation of various species of the genus *Paramecium* to the increased salinity of the medium (Gause, 1939; Gause and Smaragdova, 1939; Smaragdova, 1940). Although paramecia are typical fresh-water inhabitants, some of them also dwell sometimes in saline environments (Quennerstedt, 1865; Florentin, 1899; Kahl, 1928) and even in marine water (Levander, 1894; Calkins, 1902; Smith, 1904). It is hence interesting to analyze carefully the mechanism of their adaptation to the increased salinity of the medium.

Experimental adaptation of certain fresh-water ciliates to sea water was in recent years attempted by several authors. The delicate mechanism of the adaptive process, however, was not adequately analyzed. For example, Finley (1930) added sea water to mixed cultures of Protozoa and reported that in cases of direct dilution of cultures by sea water in increased proportions paramecia can tolerate up to 10–20 per cent, but in gradual adaptation, up to 100 per cent of sea water. These results were not confirmed by subsequent investigations. Yocom (1934), who also added sea water to mixed cultures of infusoria, observed the death of paramecia when the concentration of the added sea water attained 20–60 per cent. Frisch (1935, 1939) reported that paramecia cannot tolerate the concentration of sea water exceeding 40 per cent. Loefer (1939) also made some experiments in that direction.

In all these studies no attempt was made to evaluate the effect of natural selection in the experimental adaptation of paramecia to the increased salinity of the medium.

The first object of our investigations was to procure material with sufficient range of hereditary variations in respect to salt resistance. The isolation of single clones of infusoria from common wild cultures reveals usually only a narrow hereditary variability. Wild cultures are relatively homogeneous, because competition and natural selection are very keen in them, and only a few strong strains of paramecia usually survive. In this way relatively weaker clones drop out of the field of our observation.

In order to avoid this difficulty and to work with that wide range of hereditary variability which actually takes place in nature, and not only with a few clones which survive under some specific conditions, we isolated various clones at some stages following conjugation processes. According to older data of Jennings (1913), confirmed more recently by Raffel (1930), and also by Jennings, Raffel, Lynch, and Sonneborn (1932), recombinations of hereditary material at the time of conjugation produce numerous inherent variations in morphological and physiological characteristics of *Paramecium*.

The experiments were begun by induction of conjugation in a wild culture of *Paramecium aurelia* by a method described recently by Bar-

barin (1938). A dense suspension of paramecia about 3 c.c. of the volume was poured into a small, specially-constructed vessel, and for an hour bubbles of hydrogen were passed through it. Then the vessel was closed hermetically and the paramecia left for a night in the atmosphere of hydrogen at 25°C. Next morning air was bubbled through the liquid, and the paramecia were kept for a few hours in aerobic conditions. In consequence of such a procedure, numerous pairs of conjugants appeared in the wild culture of paramecia.

We isolated 28 conjugating pairs of *P. aurelia* into depression slides, which in their turn were put into large moist chambers kept at 20°C. On the following day both separated exconjugants (a and b) of each pair were again isolated into depression slides, and a day hence the products of the first division following conjugation (a_1 and a_2 from the first exconjugant, b_1 and b_2 from the second exconjugant) were isolated once more. In this way each pair of conjugants was the ancestor of the four separate lines of infusoria, a_1, a_2, b_1, b_2. Sonneborn (1937) has shown that the isolation of a clone in *Paramecium aurelia* at the stage of the first division following conjugation usually guarantees its hereditary homogeneity at later stages of vegetative reproduction.

We have isolated altogether $28 \times 4 = 112$ separate lines of *P. aurelia*. The four lines originating from the same pair of conjugants will be further called a family. It is known that owing to lethal combinations of hereditary material at the time of conjugation a number of lines subsequently dies out, and hence some of our clones soon disappeared. We have used in further work only 5 families of *P. aurelia*, in each of which survived all four lines. Consequently, the total number of lines of *P. aurelia* employed attained 20.

Paramecium aurelia was cultivated in Osterhout's saline medium of the following composition: NaCl—2.35 gr., $MgSO_4 \cdot 7H_2O$—0.250 gr., KCl—0.050 gr., $CaCl_2$—0.027 gr., water bidistilled in Jena glass—100 cc. This stock solution, in which the concentration of salts attained 2.7 per cent, was diluted before the experiments with bidistilled water 225 times by volume, so that the total concentration of salts attained finally 0.012 per cent. In the case of experiments with increased salinity, the stock solution was diluted with bidistilled water in such a way that the total concentration of salts attained 0.1, 0.5, 1.0 per cent, etc. Paramecia were fed by suspension of *Bacillus subtilis* and of *Torula utilis* in the saline medium. The yeast *Torula* was previously cultivated in Petri-dishes on beer-wort agar medium, and with the aid of a platinum loop transported into the saline medium. We have isolated from hay infusion a strong strain of *Bacillus subtilis*, satisfactory by its nutritive properties for paramecia, which was further cultivated on a solid medium (5 per cent hay infusion plus 1.5 per cent agar-agar). The bacteria were also removed by a platinum loop from the solid medium and added to the suspension of yeast cells.

Two other species, *Paramecium caudatum* and *P. bursaria*, were cultivated in Beers medium of the following composition: $Ca(NO_3)_2$—0.03 gr., KNO_3—0.01 gr., $MgSO_4 \cdot 7H_2O$—0.01 gr., H_2O—500 cm.^{3} The other details of cultivation were the same as with *P. aurelia*. For experiments with adaptation to salinity Osterhout's saline medium was used. This was added in various proportions to the Beers culture fluid. All these experiments were run at 25°C.

In further work we studied the adaptation of a number of clones in each species of paramecia to the gradually increasing salinity of the medium. For each clone we recorded at the start its initial resistance to salinity in the standard culture fluid, before the beginning of experiments with acclimatization. For this purpose infusoria were at first equalized in respect to nutritive conditions. Fifty individuals of each clone were placed for a day in 5 cm.^{3} of the nutritive medium. On the following day infusoria were taken from such a preparatory culture and placed by groups of four individuals into each depression slide. To each group were added 8 drops of saline medium in varying concentrations (0.3, 0.4, 0.5 per cent, etc.) without food. The cultures were left at 25°C., and on the following day the number of individuals was counted. Experiments with each clone were repeated twice and yielded a curve relating the number of survived individuals with the salinity of the water. Fig. 1 represents such a curve for the line $12b_1$ of *P. caudatum* before its acclimatization to increased salinity. In experiments with *P. caudatum* 245 such curves were obtained. The initial resistance to salinity in each clone was measured by the concentration of salts killing 50 per cent of the individuals per day (i.e. leaving still alive 2 individuals out of 4). This value was read from the concentration-toxicity curve, and

in the case of the line $12b_1$ of *P. caudatum*, shown in Fig. 1, it makes 0.47 per cent.

The same procedure was employed at different stages in the process of acclimatizing infusoria to increased salinity. The resistance to salinity measured at that time evidently exceeded the value of initial resistance. The difference between the subsequent and initial resistance to salinity in each clone gives the value of its adaptive modification. To eliminate fluctuations due to possible other causes, determinations of resistancies in the initial and acclimatized cultures of paramecia were usually made simultaneously. Experiments with various clones were performed under perfectly identical environmental conditions, and hence differences between clones in the values of

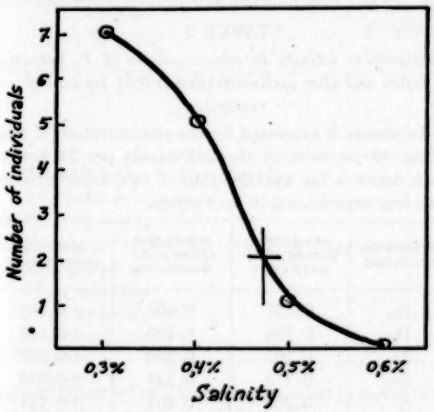

FIG. 1. RESISTANCE TO SALINITY BEFORE ACCLIMATIZATION IN THE CLONE $12b_1$ OF P. CAUDATUM

both initial resistance and adaptable modification were only due to inherent, genotypic causes.

If in the work with *Paramecium caudatum* the salinity of the medium is increased slowly, and later it ceases to increase, so that in 50 days the concentration of salts attains only 0.36 per cent, a peculiar phenomenon is observed. It appears as if physiological organization of paramecia approaches a kind of steady state, as far as we record in this case the "constancy of the total value of adaptation", which is shown in Fig. 2 and Table 1.

On the abscissae of Fig. 2 we placed the values of initial resistance to salinity in various clones of *P. caudatum*. On ordinates are put the values of adaptive modification of resistance in the same clones. It is clear that the sum of these two characters (initial adaptation plus adaptive modification)—or in other terms, the value of the total resistance, that is to say, the total adaptation to salinity—represents a constant amount in the most diverse clones. This total resistance is expressed by the following salinities: 0.688, 0.689, 0.685 and 0.690 per cent (Fig. 2).

Hence it is possible to conclude that a casual genotypic increase or weakening of initial adaptation is by no means simply added to the value of adaptive modification. It is instead observed that clones of paramecia, which are genotypically

TABLE 1

Resistance to salinity in various clones of P. caudatum before and after slow acclimatization to 0.36 per cent of salinity

Average data of two series of experiments. Resistance is expressed by the concentration of salt killing 50 per cent of the individuals per 24 hours. The test was made on the 50th day from the beginning of the experiment.

NUMBER OF THE CLONE	INITIAL RESISTANCE	SUBSEQUENT RESISTANCE	ACQUIRED RESISTANCE OR ADAPTIVE MODIFICATION
$3a_1$	0.37	0.68	+0.31
$3a_2$	0.43	0.72	+0.29
$3b_1$	0.48	0.66	+0.18
$3b_2$	0.45	0.66	+0.21
$12a_1$	0.40	0.66	+0.26
$12a_2$	0.46	0.71	+0.25
$12b_1$	0.46	0.71	+0.25
$12b_2$	0.44	0.72	+0.28
$30a_2$	0.48	0.69	+0.21
$31b_2$	0.53	0.69	+0.16
$32a_1$	0.48	0.69	+0.21
$32b_2$	0.43	0.67	+0.24

weak at the start, compensate this weakness by increased capability for adaptive modification. At the same time those clones of paramecia which are genotypically strong in the initial resistance possess but weak adaptability. In consequence of such a situation their initial strength is nullified, so far as it does not offer any advantage in respect to the total adaptation.

This conclusion is made here with some reservation, as far as the necessity of certain corrections will be evident from further experiments. Let only two points be noted at this time. (1) From the physiological point of view, a strong negative

relation of initial adaptation to adaptive modification shows that these two characters are not independent, but are instead due to activity of one and the same physiological system capable of yielding only a certain fixed amount of adaptation. When much material is spent upon initial inherent adaptation, only a little can be added to it by the way of adaptive modification. (2) From the evolutionary point of view, it is important that no simple summation of adaptability with the initial adaptation is possible.

Negative relation between initial resistance to salinity and the value of adaptive modification were also observed in experiments with *Paramecium bursaria*. Various exconjugant strains of this species were gradually acclimatized to 0.21 per cent of salinity (through the stages of 0.007, 0.07, and 0.14 per cent). Their resistance was tested 45 days after the beginning of the experiment, and the results obtained are given in Table 2.

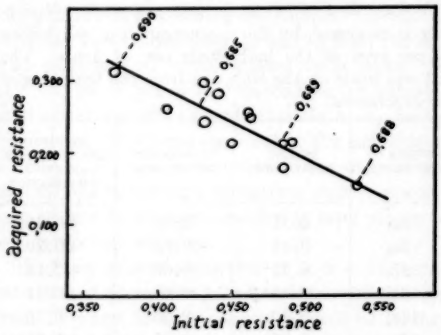

FIG. 2. THE RELATION OF ACQUIRED RESISTANCE TO INITIAL RESISTANCE TO SALINITY IN VARIOUS CLONES OF PARAMECIUM CAUDATUM
The case of slow acclimatization.

It is clear that clones $1a_1$, $1b_1$, S and R possess lower initial resistance as compared to $2a_1$ and $2b_1$, but at the same time they exceed these latter clones in respect of capability for adaptive modification. Adaptability in the inherently weaker clones is so strong, that in respect of total resistance to salinity after accimatization (i.e. by the total adaptation) these clones even overtake initially stronger strains. It follows, therefore, that the relation of initial adaptation to adaptive modification is actually negative, but that the constance of the total amount of adaptation is only approximate and by no means absolute. To this point we shall return later.

The relation of adaptability to adaptation is very interesting, and it certainly should be studied also in animals other than Protozoa. (Adaptive modification under increased salinity in a clone of vegetatively reproducing infusoria biologically corresponds to ontogenetic adaptability in multicellular animals.) One is inclined to expect theoretically the following three possibilities: negative relation, positive relation, and no relation at all between both variables. At present, however, quantitative data in this field are practically non-existent, and only one other zoölogical example is known to the writer.

Kalabukhov (1937) studied adaptations in the blood of forest mice to a mountainous mode of living. In high altitudes oxygen tension is lower than on the plain. It is well known that blood of mammals is very sensitive to the decreased oxygen tension. In order to provide the tissues with oxygen under conditions of oxygen-deficiency in the atmosphere, the number of erythrocytes and haemoglobin-content of the blood are increased. At this time only the variation in the number of erythrocytes will be considered.

TABLE 2

Resistance to salinity in various clones of P. bursaria before and after acclimatization to 0.21 per cent of salinity

Resistance is expressed by the concentration of salt killing 50 per cent of the individuals per 24 hours. Each figure is the average data of two series of tests with four experiments in each series.

NUMBER OF THE CLONE	RESISTANCE BEFORE ACCLIMATIZATION	RESISTANCE AFTER ACCLIMATIZATION	ADAPTIVE MODIFICATION
$1a_1$	0.267	0.400	+0.133
$1b_1$	0.266	0.400	+0.134
$2a_1$	0.293	0.380	+0.087
$2b_1$	0.278	0.337	+0.059
S	0.264	0.405	+0.141
R	0.262	0.400	+0.138

Kalabukhov studied several species of mice belonging to the genus *Apodemus*, including *A. sylvaticus*, *A. flavicollis*, and *A. agrarius*. Experimental transportation of mice from the plain to the mountains has shown that in high altitudes the number of erythrocytes in the blood of *Apodemus sylvaticus* increases considerably in comparison with the initial number. This species acclimatizes well in high altitudes, in spite of the deficient atmospheric pressure. The behavior of the species

Apodemus agrarius is quite different. When simultaneously transported from the plain to the mountains, the number of erythrocytes in the blood of this species increases so insignificantly that it does not provide the tissues with a proper supply of oxygen. Due to such a weak capacity for adaptive modification, this species cannot survive transportation to high altitudes, and rapidly dies out. Table 3 gives some comparative data on the alteration of the number of erythrocytes in *Apodemus sylvaticus*, *A. agrarius*, and *A. flavicollis*.

It is easily seen that when the initial number of erythrocytes is great, this character does not give any significant adaptive modification. Such is the case of *Apodemus agrarius*. In the experiments perishes. In *A. sylvaticus*, however, the number of erythrocytes is far remote from this maximal possible value. Hence this species possesses sufficient potentialities for adaptive modification.

In conclusion it should be noted that it is not the total number of erythrocytes in the blood, i.e. the total value of adaptation, but evidently only the magnitude of the adaptive modification which is important for natural selection in a population of mammals subject to a mountainous climate. Without a powerful adaptive modification in the number of erythrocytes, the increased demand of the tissues for oxygen cannot be supplied, however considerable might be the initial number of erythrocytes of the animal.

TABLE 3

Number of erythrocytes in millions per 1 mm.³ in the blood of various species of mice on the plain and after their elevation to high altitudes

From Kalabukhov (1937)

SPECIES	INITIAL NUMBER OF ERYTHROCYTES ON THE PLAIN	THE FINAL NUMBER OF ERYTHROCYTES IN HIGH ALTITUDES	THE INCREASE OF THE NUMBER OF ERYTHROCYTES (ADAPTIVE MODIFICATION)
I. Transportation to high altitudes			
1. *Apodemus sylvaticus*	8.6	9.4	+0.8
2. *A. agrarius*	9.3	9.4	+0.1
II. Prolonged action of artificially decreased atmospheric pressure			
1. *A. sylvaticus*	8.4	9.2	+0.8
2. *A. agrarius*	10.6	9.0	−1.6
3. *A. flavicollis*	7.5	9.5	+2.0

with artificially reduced atmospheric pressure the number of erythrocytes in this species even somewhat decreases. However, when the initial number of erythrocytes is small, the magnitude of its further adaptive increase is rather considerable (*A. sylvaticus* and *A. flavicollis*). The final number of erythrocytes—or, in other terms, the total value of the adaptive feature of organization—again appears to be more or less constant within the limits of the genus *Apodemus*. One again comes across strong negative relation of adaptation to adaptability, which is represented graphically in Fig. 3. One gets the impression that there exists a certain maximal possible number of erythrocytes in the blood of mice of the genus *Apodemus*. The species *A. agrarius* possesses on the plain this maximal number At the time of elevation to higher altitudes, the number of erythrocytes has, so-to-say, nowhere to expand, the adaptive modification is not formed, and this species

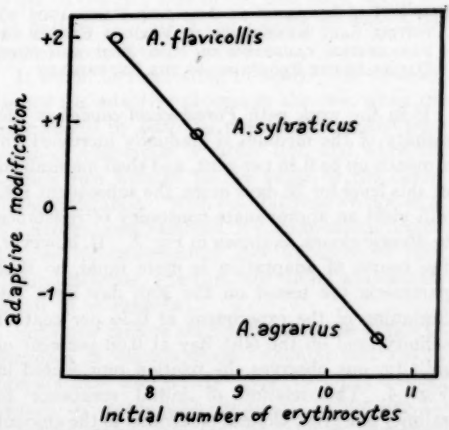

FIG. 3. THE RELATION OF ACQUIRED NUMBER OF ERYTHROCYTES TO THE INITIAL NUMBER OF ERYTHROCYTES ON THE PLAIN IN VARIOUS SPECIES OF MICE BELONGING TO THE GENUS APODEMUS

THE NON-CONSTANCY OF TOTAL ADAPTATION IN SOME ADAPTIVE CHARACTERS

It has already been remarked that the constancy of the total value of adaptation in various clones of Protozoa is approximate and not absolute. When the salinity of the medium had for some time ceased to increase, and the process of adaptation of the physiological organization of the paramecia approached to a kind of the steady state, it is true that total salt-resistance in diverse clones of infusoria is approximately constant. Experiments show, however, that in the course of active adaptation of paramecia to the increasing salinity of the medium, a characteristic deviation is observed from the constancy of the total resistance.

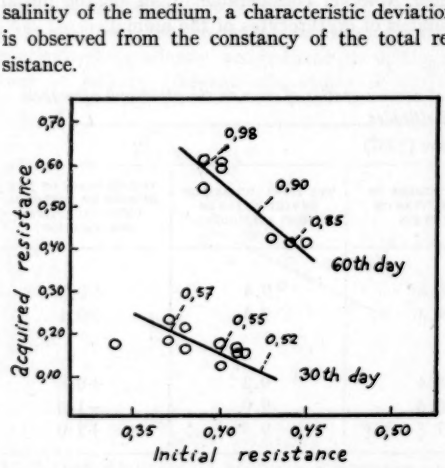

FIG. 4. THE RELATION OF ACQUIRED RESISTANCE TO INITIAL SALT RESISTANCE IN VARIOUS CLONES OF PARAMECIUM CAUDATUM ON THE 30TH AND 60TH DAY FROM THE BEGINNING OF THE EXPERIMENT

If in the work with *Paramecium caudatum* the salinity of the medium is gradually increased for a month up to 0.36 per cent, and then maintained at this level for 20 days more, the subsequent test will yield an approximate constancy of resistance in diverse clones, as shown in Fig. 2. If, however, the course of adaptation is more rapid, so that paramecia are tested on the 30th day from the beginning of the experiment at 0.36 per cent of salinity, and on the 60th day at 0.60 per cent of salinity, one observes the relation represented in Fig. 4. The relation of initial resistance to salinity of a given clone of paramecia to the amount of adaptive modification acquired by it is again negative. However, the sum of these two characters (i.e. the total adaptation) is no longer even approximately constant in various clones. Rather peculiar is the gradual increase of total resistance from the right to the left clones in Fig. 4 (0.52, 0.55, 0.57; again 0.85, 0.90, 0.98). In other words, clones initially weak in resistance acquire such powerful adaptive modifications that their total resistance to salinity outrun that of inherently stronger strains. This means that inherently weaker strains, by means of adaptive modification, are "over-strengthened." A similar picture was observed in *P. bursaria* (Table 2).

Let us attempt to appreciate these observations from the viewpoint of the hypothesis of hereditary fixation of adaptive modifications by means of natural selection of genocopies. Which clones will survive in the natural selection? It is true that natural selection requires special analysis, and this will be presented at length in the following section of this paper. At present let us only discuss briefly the advantages and disadvantages of the various clones. One is inclined to admit that in the adaptation to the increased salinity of the medium the leading part is played by the total resistance to salinity, or in other terms, by the total value of adaptation. Which part of this total resistance is inherent and which acquired is probably unimportant. It is further apparent that natural selection in the mixed cultures of paramecia will operate throughout the adaptive process. The natural selection of stronger strains certainly will not wait the attainment of the steady state, when the adaptation is in the main completed and various clones of paramecia approximately equalized in their properties. In the course of adaptation to increased salinity, the total resistance is not the same in infusoria of various clones. The strongest total resistance will be possessed by those clones which are weak at the start but powerfully adaptable (Fig. 4). All other conditions being equal, it is these strains which will survive the natural selection.

Natural selection for great total adaptation in the gradually changing environment will consequently lead to survival of strains with genotypically weakened initial adaptation and genotypically enhanced adaptive modification. This conclusion from experimental data directly contradicts the above-mentioned hypothesis of the hereditary fixation of adaptive modifications by the means of natural selection of genocopies. Natural selection under our conditions increases adaptive modifications at the expense of reducing

the strength of inherent initial adaptations resembling them.

The conclusion just arrived at means simply that in the mechanism of adaptation of *P. caudatum* to the increased salinity of the medium will take place the selection for adaptability. Such a situation is only possible because the adaptive modification makes here the lion's share of the value of total adaptation. The part played by the value of initial resistance to salinity is relatively small. A combination of the strong adaptive modification with the slight initial resistance appears to be more advantageous in respect to the total resistance than a combination of the weak adaptive modification with the strong initial resistance. At the same time, such combinations as that of strong adaptability with the genotypically strong initial adaptation turn out to be impossible for some physiological reasons.

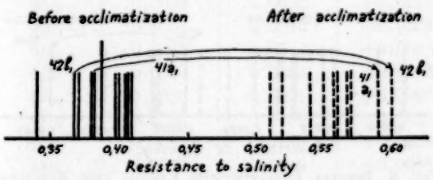

FIG. 5. INITIAL (CONTINUOUS LINES) AND ACQUIRED (DOTTED LINES) RESISTANCE TO SALINITY IN VARIOUS CLONES OF PARAMECIUM CAUDATUM

Resistance is expressed by the concentration of salt killing 50 per cent of the individuals per 24 hours.

Fig. 5 shows graphically the resistance to salinity in various strains of *Paramecium caudatum* before and after rapid acclimatization by them to the salinity of 0.36 per cent. The test was made on the 30th day from the beginning of the experiment. One is impressed by the fact that inherent diversity in the initial resistance to salinity is relatively weak, and it is much overlapped by the capability to form adaptive modifications which is peculiar to all the strains, and hence by inherent diversity in the adaptability which here arises.

The same picture is observed in experiments with 20 diverse strains of the other species, *Paramecium aurelia*. For the purpose of acclimatization these were at first placed in 0.1 per cent of salinity, three days later in 0.2 per cent and so on, until the concentration of salts attained 0.4 per cent. Under these conditions paramecia were cultivated for a week and then their salt resistance was determined by the usual method. Fig. 6 shows the data obtained, which are closely similar to those recorded for *Paramecium caudatum*.

The story heretofore reported shows that powerful capability for the formation of adaptive modifications is a necessary prerequisite condition for natural selection for adaptability. But the very feature of adaptability has behind it some historical grounds. It closely depends upon natural conditions of habitat of a given species. For example, Gause (1939) and Smaragdova (1940) recorded that *Paramecium caudatum* and *P. aurelia* more readily adapt themselves to the increased salinity than does *P. bursaria*. The two former species easily acclimatize themselves to 0.4–0.6 per cent of salinity while at the same time the increase of salinity over 0.21 per cent is usually fatal for *P. bursaria*. It is probable that weak adaptability of *P. bursaira* to increased salinity

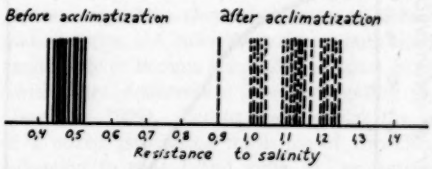

FIG. 6. INITIAL (CONTINUOUS LINES) AND ACQUIRED (DOTTED LINES) RESISTANCE TO SALINITY IN 20 VARIOUS CLONES OF PARAMECIUM AURELIA

Resistance is expressed by the concentration of salt killing 50 per cent of the individuals per 24 hours.

is due to the fact that in the peat bogs, which are the natural habitats of this species, the concentration of electrolytes is very low.

It would be interesting to analyze the mechanism of the adaptive process in the case when the part played by adaptive modification in the total value of adaptation is rather low, and when the leading rôle belongs to the value of the casual initial resistance. With that purpose we turned to the action upon Protozoa of such chemical factors as were probably never met by them in their natural habitats. In this case strong adaptability is not to be expected.

Such new factors are presented by the action on Protozoa of various drugs. Quinine and arsenic preparations are widely used to cure diseases caused by pathogenic Protozoa. They are repeatedly introduced into the infected organism, and it is often observed that parasites become acclimatized to their action and are no longer

destroyable by the drugs in usual doses. It was Ehrlich who recorded this process in his work with arsenic compounds. Whether this acclimatization of pathogenic Protozoa to the action of drugs is due to the natural selection of the more resistant strains of the parasite in the course of the treatment, or whether it depends on the formation of adaptive modifications on the part of the parasites, is not known.

We attempted to elucidate such relations by studying the action of quinine upon various strains of *Paramecium caudatum*. Paramecia were acclimatized to living in dilute solutions of quinine hydrochloride added to their standard nutritive fluid. In the first month the concentration of quinine was brought to 0.0036 per cent (through the intermediary stages of 0.0009, 0.0018 and

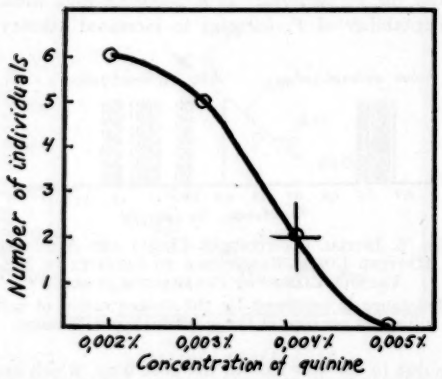

FIG. 7. RESISTANCE TO QUININE AFTER ACCLIMATIZATION TO 0.0036 PER CENT SOLUTION IN THE CLONE $42a_1$ OF P. CAUDATUM

0.0027 per cent) and in the second month to 0.0063 per cent (through intermediary dilutions of 0.0045 per cent and 0.0054 per cent). (The dynamics of acclimatizing paramecia to quinine was equalized with that employed in the experiments with salts. The concentration of 0.0036 per cent of quinine and 0.36 per cent of salt are approximate resistancies of non-adapted individuals of *P. caudatum*. Such concentrations of chemicals in the nutritive medium were reached in a month, through three equally distributed intermediary stages.) The method of testing the initial and acquired resistance to quinine in each separate clone was identical with that employed in experiments with acclimatization to salinity. Fig. 7 shows a typical curve relating the number of survived individuals with the concentration of quinine in the clone $42a_1$ of *P. caudatum* acclimatized to 0.0036 per cent of quinine. The resistance was again measured by the concentration of quinine killing 50 per cent of individuals per 24 hours.

Fig. 8 shows the distribution of resistances to quinine before and after acclimatization to 0.0036 per cent solution in various clones of *P. caudatum*. The test was made on the 30th day from the beginning of the experiment. Fig. 8 shows that casual inherent diversities between separate clones of paramecia in respect of quinine resistance before acclimatization are evidently rather considerable as compared to the slight capability to the adaptive modification, which is still present.

The mechanism of acclimatizing paramecia to quinine is evidently essentially different from their acclimatization to increased salinity. Which

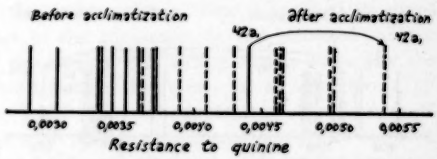

FIG. 8. INITIAL (CONTINUOUS LINES) AND ACQUIRED (DOTTED LINES) RESISTANCE TO QUININE IN VARIOUS CLONES OF PARAMECIUM CAUDATUM

Resistance is expressed by the concentration of salt killing 50 per cent of the individuals per 24 hours.

strain, in the case of quinine, will possess the greatest total resistance after acclimatization? Table 4 shows that it is the strain $42a_1$. Although this strain is, by the magnitude of its adaptive modification, much behind many of the other lines, its casual initial resistance is very strong. Due to this fact the total resistance of the strain $42a_1$ turned out to be ahead of the other strains.

In the case of quinine, adaptability will evidently not play any leading rôle for natural selection. This is again illustrated by Fig. 9. The most useful appears to be the combination of the powerful initial adaptation with the relatively moderate adaptive modification. Its total resistance attains 0.0054. Combinations of weaker initial adaptations with the more powerful adaptive modifications yield smaller values of the total resistance (0.0050, 0.0047, 0.0044). Combinations of powerful initial strength with the strong adaptability are again absent.

Summarizing, it could be stated that the acclimatization of paramecia to quinine is essentially different from their acclimatization to salinity. In the case of quinine, the conditions are favorable for the selection of the casual initial strength of resistance accompanied by the relatively moderate adaptability. At the same time, in the acclimatization of paramecia to increased salinity, a selection is inevitable for the strong adapatability accompanied by the weak initial strength. Neither in the first nor in the second case did we come across the summation of the strong adapt ation with the profound adaptability.

TABLE 4

Resistance to quinine in various clones of P. caudatum before and after acclimatization to 0.0036 per cent solution

Resistance is expressed by the concentration of quinine killing 50 per cent of the individuals per 24 hours. Average data of three series of experiments.

NUMBER OF THE CLONE	RESISTANCE BEFORE ACCLIMATIZATION	RESISTANCE AFTER ACCLIMATIZATION	ADAPTIVE MODIFICATION
$41a_1$	0.0033	0.0046	+0.0013
$41a_2$	0.0034	0.0050	+0.0016
$41b_1$	0.0037	0.0046	+0.0009
$41b_2$	0.0028	0.0043	+0.0015
$42a_1$	0.0044	0.0054	+0.0010
$42a_2$	0.0036	0.0041	+0.0005
$42b_1$	0.0030	0.0050	+0.0020
$42b_2$	0.0033	0.0036	+0.0003
$44a_1$	0.0037	0.0046	+0.0009
$44a_2$	0.0035	0.0039	+0.0004

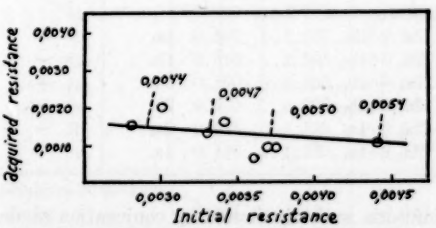

FIG. 9. THE RELATION OF ACQUIRED RESISTANCE TO INITIAL RESISTANCE TO QUININE IN VARIOUS CLONES OF PARAMECIUM CAUDATUM ON THE 30TH DAY FROM THE BEGINNING OF THE EXPERIMENT

NATURAL SELECTION FOR ADAPTABILITY

We have heretofore assumed as self-evident that the value of the total resistance of a clone of infusoria to some unfavorable environmental conditions is wholly responsible for the survival or disappearance of this clone in the process of natural selection. But it is clear that this assumption should be analyzed more carefully.

At present we possess a very delicate and conclusive method of demonstrating natural selection of some specific clones in the mixed populations of infusoria. The method is founded upon the properties of the so-called mating types of infusoria, discovered recently by Sonneborn (1937) and Jennings (1938). In the case of *Paramecium bursaria* the individuals of any given clone will not conjugate with the individuals belonging to the same clone, or to another clone if this is of the mating type identical with theirs (e.g. of the type I). At the same time they will readily conjugate with individuals of a clone which belongs to the antagonistic mating type II. The conjugation is preceded by the specific reaction of agglutination. If one mixes two clones belonging to different mating types, the individuals almost immediately agglutinate or become clumped into dense groups, which later desintegrate into conjugating pairs (Jennings, 1939). Let us now consider the case of a mixed population consisting of two clones, belonging to type I and type II, respectively. This population acclimatizes itself to the unfavorable environmental conditions. After a while one can exactly see whether both mating types of paramecia survived in the mixed culture, or whether one of them disappeared in the process of natural selection. For that purpose one must take a sample of a mixed population in appropriate physiological condition (i.e. not overfed), and add to it, in one experiment, some new individuals belonging to the type I, and in the other, of type II. If in this procedure individuals of type I will not cause agglutination of infusoria, but such an agglutination will be caused by the added individuals of the type II, this would mean that individuals of the latter type disappeared from the mixed culture. Agglutination reaction makes visible the survival or disappearance of mating types. The species *Paramecium bursaria* is particularly appropriate for such a work, because the clones of this species in continued vegetative reproduction retain for many months their specific mating types (Jennings, 1939). The situation in *P. aurelia* and *P. caudatum* is less fortunate.

In the experiments with *P. bursaria* four clones numbered $1a_1$, $1b_1$, $2a_1$ and $2b_1$ were used. The division-rate per day in these clones in the standard medium of Beers at 25°C, in the average of two series of observations, is as follows: 2.94; 3.57, 3.13, 4.23. Their initial and acquired salt resistance is given in Table 2. The following mixtures yielded immediate conjugation: $1a_1 + 1b_1$; $2a_1 + 2b_1$; $2a_1 + 1a_1$.

Conjugation was induced in the medium of Beers, and populations of conjugants from each mixed culture were gradually acclimatized to the salinity of 0.21 per cent for a period of 45 days, through the intermediary stages of 0.007, 0.07, and 0.14 per cent of salinity. At the same time the cultivation of mixed populations of conjugants was continued in the initial medium of Beers. Every three to four days paramecia living in mixed cultures were re-inoculated. For that purpose a part of the culture (about 100 individuals out of 1000) was transferred to 5 c.c. of the newly made nutritive medium. The same was the method of cultivation of separate clones. It is clear, however, that in the mixed culture must go on the process of natural selection of those clones which acclimatize and multiply more rapidly, and by this increase their relative numbers in the mixed population through a series of consecutive re-inoculations of the culture.

The test of composition of mixed cultures was made on the 45th day after the beginning of the experiment. For that purpose we mixed in the dense suspension 50 individuals from the mixed culture with 50 individuals from one of the pure strains entering into the composition of the mixture. On the following day the number of conjugants was counted. For the control, 100 individuals from the mixed culture alone were similarly isolated. The results of analysis are given in Table 5.

When the clone $1a_1$ is added to a mixed culture ($1a_1 + 1b_1$) or to ($2a_1 + 1a_1$), conjugation is observed immediately. This means that the clones with the mating type of $1a_1$ disappeared in the course of cultivation from both mixed cultures cultivated in the initial medium of Beers as well as acclimatized to increased salinity.

Natural selection in the mixture $2a_1 + 2b_1$ is somewhat different. In the saline medium the clone of the type $2b_1$ disappeared, but in the medium of Beers it was the clone $2a_1$, which perished in the mixed culture. This conclusion was confirmed by a great number of repeated tests.

The very fact of disappearance from mixed cultures of one of two mating types is interesting and suggestive. It shows that vigor or weakness of paramecia is closely bound with their mating type, so that disappearance of the weak individuals represents at the same time the disappearance of one of two antagonistic mating types. It is to be remembered that mixed cultures were started by conjugating individuals. This conjugation, as every hybridization generally, must have produced numerous new combinations of hereditary characters. If the physiological vigor or weakness of infusoria were distributed by conjugation at random and independently of the mating type, both types should later be partially eliminated from the mixed culture, and total extinction of only one of them could not have been recorded.

TABLE 5

Analysis of composition of mixed populations of Paramecium bursaria by the mating types technique

NAME OF THE CULTURE ANALYZED	NAME OF THE CLONE ADDED FOR ANALYSIS	CONJUGATION
Salinity 0.21 per cent		
$1a_1 + 1b_1$	$1a_1$	+
$1a_1 + 1b_1$	$1b_1$	−
$2a_1 + 2b_1$	$2a_1$	−
$2a_1 + 2b_1$	$2b_1$	+
$2a_1 + 1a_1$	$2a_1$	−
$2a_1 + 1a_1$	$1a_1$	+
Initial medium of Beers		
$1a_1 + 1b_1$	$1a_1$	+
$1a_1 + 1b_1$	$1b_1$	−
$2a_1 + 2b_1$	$2a_1$	+
$2a_1 + 2b_1$	$2b_1$	−
$2a_1 + 1a_1$	$2a_1$	−
$2a_1 + 1a_1$	$1a_1$	+

At the same time these experiments represent a direct proof of strong natural selection among closely related clones in the mixed populations of infusoria. In what the weakness of perished clones consists is rather clear. The salt resistance of the clone of the mating type $2b_1$, which disappeared in the course of acclimatization to salinity, is lower than that of the survived clone $2a_1$ (Table 2). The division rate per day of the clone $1a_1$

(2.94), which disappeared in the medium of Beers, is lower than the division rate of the better fitted clone $1b_1$ (3.57).

In a number of other experiments natural selection in the mixed cultures of infusoria was studied by a different method. We simultaneously acclimatized to the increased salinity of the medium various isolated clones, and also cultures consisting of all these clones combined together. We have always observed that salt resistance of individuals from a mixed culture approaches that of the most resistant strains entering into its composition. It was hence concluded that these most vigorous strains survived in the mixed culture, and that the whole population consists of them alone.

Tables 6 and 7 show the data obtained. In *P. aurelia* the average resistance to salinity of 20 separately acclimatized clones attains 1.129. If there were no natural selection at the time of acclimatization of mixed cultures, such would be also the resistance of a mixed population, so far as at the beginning of the experiment it consisted of members of 20 separate clones mixed in equal numbers. The observation shows, however, that the

TABLE 6

Resistance to salinity in various clones of P. aurelia before and after acclimatization to 0.4 per cent of salinity

Resistance is expressed by the concentration of salt killing 50 per cent of the individuals per 24 hours. The test was made on the 20th day from the beginning of the experiment.

NUMBER OF THE CLONE	RESISTANCE BEFORE ACCLIMATIZATION	RESISTANCE AFTER ACCLIMATIZATION	ADAPTIVE MODIFICATION
$1a_1$	0.470	1.140	+0.670
$1a_2$	0.422	1.080	+0.658
$1b_1$	0.500	1.145	+0.645
$1b_2$	0.477	1.090	+0.613
$2a_1$	0.525	1.165	+0.640
$2a_2$	0.458	1.230	+0.772
$2b_1$	0.480	1.240	+0.760
$2b_2$	0.485	1.100	+0.615
$3a_1$	0.480	1.195	+0.715
$3a_2$	0.465	1.120	+0.655
$3b_1$	0.520	1.015	+0.495
$3b_2$	0.520	1.230	+0.710
$4a_1$	0.520	0.900	+0.380
$4a_2$	0.540	1.210	+0.670
$4b_1$	0.507	1.130	+0.623
$4b_2$	0.510	1.105	+0.595
$5a_1$	0.550	1.160	+0.610
$5a_2$	0.430	0.990	+0.560
$5b_1$	0.455	1.125	+0.670
$5b_2$	0.430	1.200	+0.770
Average of 20 isolated clones	*0.487*	*1.129*	*+0.642*
Mixed population No. 1	*0.487*	*1.230*	*+0.743*
Mixed population No. 2	*0.487*	*1.245*	*+0.758*

TABLE 7

Resistance to salinity in various clones of P. caudatum before and after rapid acclimatization to 0.36 per cent of salinity

The test was made on the 30th day from the beginning of the experiment.

NUMBER OF THE CLONE	RESISTANCE BEFORE ACCLIMATIZATION	RESISTANCE AFTER ACCLIMATIZATION	ADAPTIVE MODIFICATION
$41a_1$	0.40	0.57	+0.17
$41a_2$	0.38	0.59	+0.21
$41b_1$	0.41	0.57	+0.16
$41b_2$	0.41	0.56	+0.15
$42a_1$	0.41	0.56	+0.15
$42a_2$	0.40	0.52	+0.12
$42b_1$	0.37	0.60	+0.23
$42b_2$	0.34	0.51	+0.17
$44a_1$	0.38	0.54	+0.16
$44a_2$	0.37	0.55	+0.18
Average of 10 isolated clones	—	*0.557*	—
Mixed populations	—	*0.620*	—

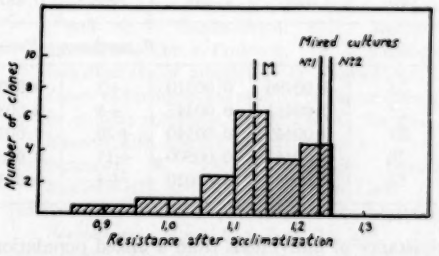

FIG. 10. VARIATION IN SALT RESISTANCE AFTER ACCLIMATIZATION IN 20 SEPARATE CLONES OF P. AURELIA
M is the average salt resistance of 20 isolated clones. Continuous vertical lines show the resistance of mixed cultures.

resistance of an acclimatized mixed population is greater and makes 1.230 and 1.245. This is also evident from Fig. 10, which shows the variation in salt resistance after acclimatization in 20 separate clones of *P. aurelia*. The resistance of individuals from a mixed culture approaches that of the several most vigorous clones. It is hence evident that these clones alone survived natural selection in a mixed population. The same story is repeated in the cultures of another species, *P. caudatum*. Table 7 shows that the average salt resistance of 10 isolated clones of this species is 0.557, but the vived in the mixed culture. The names of the survived clones being thus known, it was easy to calculate their average initial resistance to salinity. In a similar way we calculated the average adaptive modification for all the isolated clones of paramecia, and on the other hand, the average adaptive modification (from the figures of isolated clones) of those which remained in the composition of the mixed culture.

The results of such calculations for populations of *P. caudatum* are given in Table 8. It is clear that the average initial salt resistance of those

TABLE 8

Resistance to salinity and quinine solutions in Paramecium caudatum and P. aurelia

TIME IN DAYS FROM THE BEGINNING OF ACCLIMATIZATION	RESISTANCE AFTER ACCLIMATIZATION			RESISTANCE BEFORE ACCLIMATIZATION			ADAPTIVE MODIFICATION		
	Average for isolated clones	Average for mixed population	Increase of mixed population in per cent	Average for isolated clones	Average for clones survived in mixed culture (by calculation)	Increase of mixed population in per cent	Average for isolated clones	Average for clones survived in mixed culture (by calculation)	Increase of mixed population in per cent
				P. caudatum: Salt resistance					
30	0.567	0.625	+10	0.384	0.375	−2	0.183	0.238	+30
25	0.523	0.595	+14	0.352	0.345	−2	0.171	0.210	+23
27	0.583	0.640	+10	0.428	0.432	+1	0.155	0.182	+17
56	0.954	1.000	+5	0.438	0.424	−3	0.516	0.610	+18
61	0.893	0.960	+7	0.393	0.392	0	0.500	0.528	+6
				P. aurelia: Salt resistance					
20	1.129	1.237	+9.5	0.487	0.485	−0.4	0.642	0.737	+15
				P. caudatum: Resistance to quinine solutions					
33	0.00496	0.00510	+3	0.00387	0.00386	0	—	—	—
25	0.00411	0.00445	+8	0.00321	0.00330	+3	—	—	—
27	0.00449	0.00540	+20	0.00321	0.00343	+7	—	—	—
28	0.00452	0.00500	+11	0.00347	0.00358	+3	—	—	—
58	0.00981	0.01020	+4	0.00379	0.00405	+7	0.00602	0.00543	−11

resistance of individuals from a mixed population attains 0.620.

An attempt was made to investigate the point whether the clones that survived possess strong initial salt resistance, or whether they exceed others in the capability for adaptive modification. We have consequently performed the following calculations. In each series of experiments the resistance of an acclimatized mixed population was compared with the resistance of all separately acclimatized clones. From such a comparison it was determined which clones most probably survived in mixed cultures is somewhat below the average initial resistance of the whole group of clones. On the other hand, the adaptive modification of survived clones much exceeds the average adaptive modification of all the clones. A similar picture is recorded for *P. aurelia*.

On the basis of the data given in Table 8 it is possible to conclude that in the acclimatization of paramecia to the gradually increasing salinity of the medium, natural selection of the clones actually occurs with powerful adaptability but rela-

tively weak initial adaptation. Natural selection contributes to further increase of adaptability by casual inherent variations in that direction. In this way the preliminary conclusions of the previous section of this article made on the ground of study of total salt resistance, and of its fractionization into constituent adaptability and adaptation in various isolated clones, are entirely confirmed by the direct study of natural selection in mixed cultures.

What, however, occurs in the case of adaptation of *P. caudatum* to dilute solutions of quinine? Table 8 shows that there is a clear selection in mixed cultures for great total resistance, so far as the resistance of the acclimatized population exceeds the average resistance of isolated clones. In distinction from adaptation to salinity, a great initial resistance of a clone to the action of quinine guarantees to it some advantage in natural selection. This conclusion directly follows from the fact that the average initial resistance of the clones survived in mixed cultures exceeds the average resistance of all the isolated clones. On the other hand, the magnitude of adaptive modification of survived clones is by 11 per cent behind that of all the clones studied. This again confirms the conclusions of the previous section.

SUMMARY

The relation of adaptability to adaptation within the population of one and the same species is negative, i.e. the stronger the initial inherent adaptation the weaker is the adaptability, and vice versa. This conclusion follows from observations on unicellular organisms, but it was shown to agree well with the data obtained in the work with other animals.

In the adaptation of animals to gradually changing environmental conditions, the magnitude of genetic diversity in the adaptability of different individuals in a population is very important as compared to the magnitude of diversity of the same individuals in their inherent initial strength. In the case of adaptation of *P. caudatum* and *P. aurelia* to the increasing salinity of the medium, the larger part of total adaptation is due to adaptability. The clones that survived in mixed cultures are here weak in the initial strength but powerfully adaptable. On the other hand, in the case of acclimatization of *P. caudatum* to dilute solutions of quinine, adaptability is low as compared to magnitude of inherent diversities of various clones in the initial resistance. It is consequently the profound initial strength which is important for the survival of a clone in the mixed culture. The survivors here are well adapted but poorly adaptable.

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THE PHYLOGENY OF SOCIAL NESTING HABITS IN THE CROTOPHAGINAE

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INTRODUCTION

THE reproductive behavior of birds is based on the construction and maintenance of a nest. Normally a male and a female select a nest site and build a complicated structure for raising the young. Although nesting behavior is not limited to birds, nevertheless the habits reach their climax in variety and complexity in this class. The variations in nesting behaviors are innumerable and frequently demonstrate phylogenetic sequences.

The Crotophaginae, one of the six subfamilies of Cuckoos, has developed the unusual habit of building communal nests in which several females lay eggs. The phylogeny of this remarkable system of raising young is the subject of this paper. The family Cuculidae as a whole shows a tendency to develop peculiar breeding habits. Of the approximately 200 species of Cuculidae, about 80 are parasitic (Makatsch, 1937), representing two of the six subfamilies. This parasitism is found in several stages of development. Some species perhaps are just starting on the road to parasitism; for example the eggs of the Yellow-billed Cuckoo (*Coccyzus americanus*) have been found in the nests of at least 12 species of birds (Herrick, 1910). Other species are always parasitic. The least specialized of these lay eggs in the nests of numerous species. In other cases, as represented by the European Cuckoo (*Cuculus canorus*), the birds are individually host-specific (Friedmann, 1928a). Thus individuals of the species each parasitize particular host species, although in the same region other individuals may lay eggs in nests of other host species. The climax has been reached by certain species, such as *Eudynamis honorata*, which parasitize only one species in a region. The Crotophaginae, however, instead of developing parasitism as other cuckoos have done, have specialized in the direction of social nesting habits.

Before considering the background of the subject let us now proceed to review briefly the subfamily Crotophaginae. This group of birds consists of the monotypic genus *Guira* and the genus *Crotophaga*, the latter represented by three species: *major*, *sulcirostris*, and *ani*. The distribution of the subfamily extends from Rio Negro in Argentina north throughout the West Indies to Florida and throughout Central America to Texas. The birds have noisy, ostentatious habits and everywhere are abundant and conspicuous members of the avifauna.

At this point, in order to orient the reader, a brief description of the behavior of the species is inserted. All four species of the subfamily possess the same general behavior patterns and for the purposes of this paper may be described in general terms. The species prefer fairly open and moist habitats and are conspicuous in behavior, all using loud notes and making no effort to conceal themselves. The birds associate in flocks of about a dozen individuals, spending the days together and sleeping in the same tree. Each flock defends its territory by fighting. At the breeding season members of the flock cooperate in the building of a single nest in which several females may lay eggs. The males assist in the construction of the nest and in the care of the young. After the breeding season the young stay with the flock for a variable length of time and may help in the care of the next brood, and may even breed with the colony the next season. During the non-breeding season the birds tend to congregate in moist areas where insects, their favorite food, are most abundant. The composition of the flock varies over a period of time; a bird may leave, or, after a period of fighting, join the group. In connection with the flock behavior are many calls and actions which are of value to the group as a unit.

These species, whose behavior has been briefly

described, show the development of a system of social nesting. The phylogeny of breeding habits within a group of animals is usually obscured by the extinction of some of the species which represent stages in the development. This situation makes it necessary to speculate and to reason from analogy. In some cases, however, the evolution of behavior may be traced through a small group of closely related species, as Friedmann (1929) has done in the Cowbirds. The Crotophaginae is another group of birds in which we are able to trace the steps in the evolution of a peculiar type of breeding habits, as this paper endeavors to show. The phylogeny of other groups of animals has been studied from the behavioristic viewpoint, for example, the ants in Wheeler's classic studies (1923, 1928). Emerson (1938) analyzes the nests of termites to trace the behavioristic and evolutionary sequences.

In discussing the evolution of any particular condition in animals it is customary to seek "causes" which determine the "effect." This principle of Cause and Effect, however, encounters numerous philosophical difficulties and in biology is further complicated by the simultaneous action of several factors. For the purposes of this paper, then, we shall not discuss any cause of the development of social nesting habits but merely state the conditions under which the breeding behavior evolved. From the evidence here presented it will be seen that social nesting habits are the logical outcome of these conditions and that, in this case, were any one of the several factors lacking, the habits probably could not have developed. These same habits, of course, probably could have resulted from a different evolutionary history. In addition it should be noted that the unusual social nesting, as found in the behavior of *Crotophaga ani*, is the result of a combination of situations, no one of which is in itself unusual, but all of which when combined, permit the social nesting. These various conditions may be regarded as conductive to the development of the habit. Throughout this paper examples of other species will be cited to show that none of the particular behavior patterns is unique but that all occur in one or more groups of birds.

Before considering in detail the behavior of the birds, it is desirable to discuss some features of their anatomy and then their geographical distribution. In their internal anatomy the various species show no significant differences. Of the external features the development of the keel on the bill in the members of the group is spectacular. *Guira* has a typical cuculine bill but the genus *Crotophaga* has developed a large thin keel on the bill. In *Crotophaga major* the keel extends one-half way to the tip of the bill and in *C. ani* the keel is high and thin, extending to the tip. In *C. sulcirostris* the keel is grooved. In coloration *Guira* is again obviously the most closely allied to to the other cuckoos. Its body feathers are white but the tail, wings, and head are streaked with brown and some black, giving the appearance of a brown bird; a notable feature is the crest of feathers on the head. The genus *Crotophaga* is uniformly black, with a different amount of blue irridescence in the plumage of each species. Both *major* and *ani* have a remnant of the crest on the head as shown by a few feathers which are slightly longer than the others. The evidence from the external features indicates that *Guira* is positively the more primitive genus and that within the genus *Crotophaga*, *C. ani* is probably the most evolved. The development of the bill and the black color and the reduction of the crest are evidence of evolution within the group.

Concerning the geographical distribution of the subfamily it may be said that the group is either very young or more probably has been unable to spread very far because of a lack of ability to adapt itself to colder climates. *Guira* is found in Brazil and Argentina. *C. major* is found from northern Argentina through Brazil to Panama. *C. sulcirostris* occurs on the west coast from northern Peru through Central America to Texas. *C. ani* is the most widespread, occurring from northern Argentina to Yucatan and Florida and also through the West Indies. This distribution suggests a gradual dispersal from the highlands of Brazil.

With this introduction as a background we shall now consider the phylogeny of behavior. A preliminary section brings together notes on comparative behavior within the subfamily and reference to problems of discrimination and to "releasers". The stages in the evolution of social nesting are next analyzed. The development occurs at three levels, represented by the species (1) *Guira guira*, (2) *Crotophaga major*, (3) *C. ani* and *C. sulcirostris*. The primary factors conducive to the development of social nesting habits are (a) modification of territorialism (b) aberrant breeding, (c) the type of habitat. These three levels of development will be analyzed in a separate section for each of the

above factors. Finally there is a discussion of the phylogeny of behavior within the group and its general relation to social parasitism.

COMPARATIVE BEHAVIOR OF THE CROTOPHAGINAE

The author has had the opportunity to observe the same species in very distant parts of its geographical range. The study of a species in one particular locality may be misleading because of certain local mannerisms. Since studies of the same species of bird, carried out by the same observer in widely separated places, are rare, these data are considered worth reporting in some detail. The following notes are recorded in order to afford a comparison of the habits of *Crotophaga ani* in British Guiana and in Argentina with the habits of the species in Cuba (Davis, 1940a).

In British Guiana each flock strictly maintains a territory exactly as in Cuba. However, the vegetation of certain areas permits an apparent variation in behavior. For example, along the Abary River are occasional open areas of savanna, always surrounded by rain forest. Many of these areas are not large enough for more than one group of *C. ani* and hence in these cases no territorial fighting can appear between groups, for there are no neighbors with whom to fight. However, the occasional stranger is driven out by fierce fighting. Another modification of the territory is that *C. major* is permitted to share the territory. Certainly there is competition for food between the two species.

The colonies found in Guiana were smaller than many found in Cuba. For example, on July 13, 1939, I found a colony with five adults and a nest containing one young bird. Another colony containing six adults had three young, two weeks old. A month later I found a colony with four adults (two females, one male, one of unknown sex) and a nest containing four young ready to leave the nest. It should be noted that in these groups probably only one female laid in each nest, for in no case were there more than six young birds.

Observations on *C. ani* were made also near Saladas in the Province of Corrientes in Argentina. Here the species is not sufficiently abundant to show territorialism clearly. One group of birds (12), including some juveniles, inhabited a particular area, near a small marsh. Also another colony, consisting of three adults, had a nest with three young. Several times an individual or two of *Guira guira* came near and even perched in the same tree with an individual of *C. ani* without causing the latter to show defense of the territory. Again it is of importance that, as in British Guiana, the territory is not defended against a species so closely related, both taxonomically and ecologically. In summary it may be said that in the general activities, as well as in the particular habits mentioned above, the behavior of *C. ani* is the same in British Guiana, in Argentina, and in Cuba.

Correlation of anatomy and behavior

An interesting relationship between anatomy and behavior is shown in the Crotophaginae. It is considered that a display behavior develops before the particular structure used in the display; the wing marks of the ducks are the classic example. Lorenz (1935) describes the uses in herons of certain structures for elaborate display. Chapman (1935) calls attention to the fact that a manakin of Brazil (*Chiroxiphia*) has an elaborate dance but no special structure such as is found in other members of the family. A corollary of this principle is that the structure remains after the behavior has disappeared. The development of the crest in the Crotophaginae may be an example of this corollary. The large crest of *Guira* is raised in alarm and also when the alarm rattle is given. *C. ani* has no such alarm note but has retained some feathers on the head which are somewhat longer than the nearby ones. This little crest is never used. This retention of a structure after the behavior is lost follows naturally from the fact that the structure is developed after the behavior.

Conspicuous buccal markings are found in the nestlings of *Guira* and also of *C. major*. In *C. ani* these markings are present but much less distinct.

Social behavior

The similarity of the call notes throughout the group is of interest. *C. ani* has the most varied vocabulary and is the most social. The alarm call of *C. major* greatly resembles the rattle alarm of *Guira*. But the most noteworthy is the resemblance of the flight flock call, the note used to notify other members of the group of the movements of one individual. In *Guira* the note is weak and indistinct. In *C. ani* the note is nearly identical in pitch but is very loud and harsh. The use is the same in both cases. The flight flock call of *C. sulcirostris* is of the same pattern. The

notes used in mating are in the whole group a uniform series of soft whines.

The Crotophaginae agree with most other birds in having two calls to indicate danger. The 'alarm' call notifies the members of the group of a walking enemy or suspicious situation. The 'danger' call is used to warn of an approaching hawk or other flying predator. Many species of birds have this separation by call of the types of danger. Makkink (1936) found in the Avocet (*Recurvirostra avocetta*) that there was one call for the chief enemy, the gulls, and another for all other enemies.

Social behavior has nearly always developed coincident with an extension of the time the young remains with the adults (cf. ants, wasps, and humans). In the Crotophaginae, however, there is no evidence that social nesting or flock behavior is a result of this extension. Nevertheless it is of great interest that the young of one brood have been observed feeding the young of the second brood in *C. ani* (Davis, 1940a) and also in *C. sulcirostris* (Skutch, 1935). Furthermore, as Skutch points out, it is not unusual for unmated birds of many species to assist at the nest. Skutch (1940) found that the young of some wrens remain with the adults and even feed the young of the succeeding brood. According to Leach (1925), the young California Woodpeckers (*Balanosphyra formicivora*) also feed the young of the second brood. Thus we see that the cohesion of the family in several species of birds is the result of communal nesting, but not the cause.

The type of peck order or social hierarchy is of great importance in a social group. In the Crotophaginae no suitable behavior was found which could be used to rank the birds. While feeding, contests for juicy morsels occasionally occurred but showed no peck order. Lorenz (1938) points out that when there is a rigid peck order in colonial birds only one pair can raise young. In the Jackdaws (*Coleus monedula*) this situation is overcome by the fact that the despot pecks only the nearest in rank. In the Crotophaginae if a peck order occurs, a similar situation probably obtains.

Discrimination

Under the term, discrimination, many problems of animal behavior are grouped. The problem in general is to analyze a series of behaviors to determine which characteristics of the stimulating object act on which sense organs of the reacting animal to influence a subsequent behavior. In birds the stimulating characteristics are usually some morphologic or behavioristic element. The reacting organs are generally visual or auditory. In this paper is discussed the evidence concerning the discrimination of three of the many objects occurring in the bird's life, namely, the sex-partner, other individuals of the species and the boundaries of the territory.

The evidence concerning the discrimination of the sex-partner is meager. The problem is to find out what features of a bird are the clues which make possible the determination of the sex. In appearance the sexes are identical in all species of Crotophaginae except that the male is larger. Experiments with dummy birds were performed on *Crotophaga ani*. These dummies were museum skins arranged to resemble a live bird. In most cases the birds attacked the dummies as if they were live invaders of the territory. Sometimes after the dummy had been in one place a long time the owners of the territory ignored it. Decoy (live) birds, placed in a trap in order to catch the birds, were treated exactly like strangers and killed in a short time. Young birds, however, were ineffective as decoys because the adults did not respond in either a helpful or an antagonistic manner. The above evidence suggests that the Crotophaginae belong to the "labyrinth fish" type of mating reaction according to the classification of Lorenz (1935). In this category the display of the male develops into fighting except when the stranger shows female behavior. However, the assignment of the Crotophaginae to this category depends on insufficient evidence. In no case was "female behavior" observed to result in a cessation of fighting. This is, of course, not contradictory evidence but merely lack of evidence.

An important modifying condition is the relationships imposed on the individuals by the flock organization. It seems likely that an individual must be admitted to the flock before it can be eligible for pairing. If this is true then all the fighting observed was in reference to membership in the flock and none in reference to the sex-partner. If this is the case then we must admit that we have no evidence as to the method of discrimination of the sex-partner.

Another problem is to determine which sense modalities are used in discrimination of other members of the species or of other species. There is no doubt that each member of the flock knows

individually every other member of the group. (Cf. Davis, 1940a, 1940b, 1941a.) The problem is to determine which sense modality is used in this discrimination. A natural experiment occurs in the presence of the species *Ptiloxena atroviolacea*, an entirely black Icterid about one-third smaller than *Crotophaga ani*. *C. ani* persecutes this species and drives it from the territory. The behavior towards *Ptiloxena* consists of the same series of patterns used against an intruder of the *Crotophaga* species. Another black species in the region, the rare *Corvus nasicus*, was seen only once and at that time was being persecuted by a group of *Crotophaga ani*. *Holoquiscalus niger*, another Icterid, was not observed to be persecuted—a situation probably due to the ecological separation of the habitats. As further evidence it may be noted that, according to the natives of Cuba, albino birds live with the flock in a normal manner; the writer never observed an albino bird. The above facts, showing that black birds of other species in addition to dummy birds are attacked, suggests that the discrimination is by means of vision and not by audition. That the auditory sense modality is used in certain species is shown by the work of Noble, Wurm, and Schmidt (1938) who found that herons (*Nycticorax nycticorax*) recognize their sex-partners by voice. Experiments with mirrors (Davis, 1940a) show that individuals of *Crotophaga ani* do not recognize themselves but fight against their own image. This evidence eliminates the olfactory sense modality, already improbable, from consideration.

Now, having outlined the evidence and suggested the conclusion that these birds utilize the visual sense modality for the discrimination of other individuals, it is necessary to consider what characteristics of the stranger stimulate the reacting bird. In general the problem is to determine whether behavior or physical appearance is the basis of discrimination. The evidence from the reactions to *Ptiloxena* and to the dummies suggests the conclusion that strange birds are recognized not by their behavior but by their appearance. Were behavior the means of discrimination only birds which behaved in a certain manner would be attacked. But birds are driven out which resemble *Crotophaga* in appearance although their behavior has no resemblance to that of an invading bird. The tolerance of *C. major* by *C. ani* in Guiana is an apparent exception which may be explained by assuming that the *ani* have learned to recognize the *major* as individuals. It must be remembered that for the moment we are concerned with the recognition, not of the sex-partner, but of a stranger. Nevertheless, the data pertaining to the recognition of a sex-partner are useful in an attempt to analyze the situation in the Crotophaginae. Referring to other species, the Kingbirds (*Tyrannus tyrannus*) (Davis, 1941b) drive from their territory birds of various species whose behavior varies greatly and whose only common characteristic is an appearance different from that of the female. Tinbergen (1939) refers to errors of identification by the Snow Bunting (*Plectrophenax nivalis*). In these cases the behavior of the female is of the type which should indicate that she belongs in the territory. However, the male does not recognize the physical features of his mate and starts to fight until her features are recognized. Tinbergen also found that the male Bunting requires some time to learn to recognize his mate and until that time threatened her whenever she came into his territory. Lorenz (1935) states that a young bird must learn a certain number of characteristics of the parent before becoming able to recognize and thus not threaten it. The Jackdaw is a species which certainly does recognize the individuals of the flock by appearance, not by behavior. Also, Lorenz points out that the social life of birds differs from that of insects because there is a personal recognition of the individuals in the group. Noble and Vogt (1935) found that some species (*Agelaius phoeniceus* and *Geothlypis brachydactyla*) which differ in the plumage of the sexes, recognize the female by physical appearance. Noble (1936) carried the work further and found that the 'moustache' of the Flicker (*Colaptes auratus*) was necessary for sex recognition. In contrast, other species, which frequently are identical in the plumage of both sexes, recognize individuals by behavior (Noble and Vogt, 1935). Lorenz (1935) found that young herons recognize their parents by behavior. This evidence from other species suggests the possibility that even in the Crotophaginae the initial recognition of a stranger is by means of the behavior of the individual. This suggestion is supported by the work of Noble and Curtis (1939). In the Jewel Fish (*Hemichromus bimaculatus*) the sex of a stranger is recognized initially by behavior but after pairing the mates recognize each other by individual characteristics of appearance. In the Crotophaginae it is difficult to determine

exactly what the behavior might be which would indicate that a strange bird is not a member of the group. However, the lack of knowledge of the territory may be noticable to the owners. Then on close inspection the owners may see that the bird is a stranger and drive it out. Also there is the possibility that a lack of certain positive behavior patterns identifies a bird as being a stranger.

In addition to the question of discrimination of individual birds there is the problem of the discrimination of the boundaries of territories. The birds remain so strictly in their own territory that there must be an exact knowledge of the very trees and shrubs which mark the edge. In Cuba it was most amusing to watch the members of a group follow the electric mowing machine which the birds had learned was a source of an easy meal of insects. Each group followed the machine to the exact boundary of the territory but did not trespass beyond, in spite of the strong attraction of food. The birds clearly recognized the individual trees or bushes which marked the boundary.

Members of the Crotophaginae are able to recognize individuals which seem identical to the human observer. Yet these same birds are unable to recognize that such a bird as *Ptiloxena* is of another species. These facts suggest a conflict in the interpretation. It seems likely that this apparent discrepancy may be resolved by a consideration of the probability that birds learn one or two special characteristics of each individual bird and unless these are present, consider the individual to be a stranger. Lack (1939) found that only a few characteristics of the English Robin (*Erithacus rubecula*) were required to cause the owner of the territory to attack a dummy. In humans the ready deception accomplished with disguises shows how very few marks we need to recognize our friends.

Releasers

The fact that a certain few characteristics are used to discriminate among individuals of the same species is further evidence that social behavior is largely controlled by specific combinations of special stimuli. These stimuli are anatomical structures or behavior patterns which are in themselves unusual or are combined in unusual behavior sequences. Such sequences are of so improbable a nature that they do not occur in the experience of the species except under the proper circumstances. Therefore, the automatic and inflexible response to the stimulus occurs only at the proper time. Such stimuli or series of stimuli have been called releasers (Von Uexkill and Lorenz) or sign-stimuli (Russell, 1934). The studies of the Crotophaginae have provided examples of several releasers which it is proposed to mention at this time. On one occasion a dove (*Zenaidura macroura*) fluttered off her nest, performing typical injury-feigning, right into the midst of a group of anis. The birds at once acted toward the dove as if it were a wounded individual of their own species. They crowded around the dove, fluttered and used a chuckle note. They did not use the 'conk', a note uttered while attacking a stranger. As another example the mutual preening has many of the characteristics of releasers. The moment that the bill of one bird touches the neck of its neighbor the neck is raised and the feathers fluffed out. This occurs in all species of the subfamily. This action may be no more than a simple reflex. The feeding of the young of the second brood by the young of the first brood is probably a social companion action. It is possibly released not by the young in the nest but by the action of the other adults.

The imperfections of releasers are probably as informative as the perfections. Witness the interesting conflict between the response to the alarm call and the strict observance of the boundaries of the territory. When the investigator disturbed a nest, the alarm call was used and the birds from nearby groups came near but they never passed the boundaries of the territory although it was obvious that the alarm call was a strong attraction. As another example of an imperfection of releasers, individuals of the Mockingbird (*Mimus polyglottos*) were able to mimic the alarm call and released the alarm behavior of the nearby anis. This observation shows that the discrimination was not very exact for even the writer could distinguish after short practice between the mocker and the true alarm note.

MODIFICATION OF TERRITORIALISM

The concept of territorialism has developed from attempts to interpret various types of fighting behavior of animals. This concept has had great heuristic value and in addition has clarified the interpretation of the behavior of many species. In other species (Cowbirds) the analysis of the manifestation of territorialism has suggested a

possible course of phylogeny of behavior. It is now proposed to present the relation of territorialism to the phylogeny of behavior in the Crotophaginae and then take up the modifications of the concept as suggested by the behavior of the Crotophaginae. This chapter emphatically is not a critique of the theory of territorialism or of the many criticisms of the concept.

In all the species of the subfamily the colony owns a territory which consists of two distinct parts. One of these is a clump of trees for sleeping and the other an area of fairly open land for feeding. From this territory, in general, other members of the species are expelled. Among the species, however, certain differences exist. *Guira guira* defends its territory only slightly; numerous intrusions are permitted, although on some occasions birds are violently driven out. The colony lives in a large but nevertheless definite area, and, since it is defended, it can be called a true territory. The important point is that within this colonial territory one or two pairs may have their own small territories. One or more pairs may separate from the colony and build a nest, setting up around this nest a territory from which intruders are expelled. However, the defence of this small territory is not vigorous and in many cases other birds of the colony use the nest, thus producing a communal nest. This weak defence of the territory has thus permitted social nesting.

In *Crotophaga major* the development of social nesting has continued. The birds remain in pairs, all cooperating to build one nest in which several females lay eggs. Probably not all females lay eggs at the same time and also probably a single pair does occasionally build a nest and raise young. The colony defends the territory for the whole group, although weakly. Lack of defence is probably more apparent than real and depends on a mutual understanding. Such behavior occurs in other species. For example Ryves (1929) found that in Redshanks (*Totanus totanus*) "once an individual territory has been definitely secured by a pair of birds and approved by the other pairs of the same species, a distinct mutual understanding if not friendship developed among them."

In *Crotophaga ani* the communal nesting has reached its climax. Each colony defends its territory most aggressively and without exception attacks strangers. The marital relations are very flexible. Polygamy is the general rule for it is certain that in some cases polyandry occurred and in others polygyny prevailed. Yet in some groups monogamy was strict and there was no dissension among pairs. In one case a pair created a territory and defended it alone. Wetmore (1927) cites two instances in which he believed that a single pair built a nest.

Crotophaga sulcirostris is apparently at the same level of development as *C. ani*. The observations of Skutch (Bent, 1940) indicate that the birds have the same marital relations as does *C. ani*.

The phylogenetic development of social nesting coincides with the disappearance of territorial defence by the pair and the appearance of territorial defence by the colony. Other species have developed social breeding habits of several types, which can be roughly contrasted with the stages in the Crotophaginae. Several examples of these species will now be cited to illustrate for comparison the three levels in the development of crotophaginine social nesting.

At the phylogenetic level of *Guira* may be cited the numerous species which spend most of the year in flocks but separate out into pairs for breeding. A few examples will suffice. Tinbergen (1939) found that Snow Buntings separated from the flock to acquire territory. The Oyster-catcher (*Haematopus ostralegus*) (Huxley, 1925) has a nesting territory but a common feeding ground. The coveys of Bob-white (*Colinus virginianus*) (Errington, 1933) break up in April to pair for breeding. These examples show that a weakened territorial defence by a pair under certain conditions could permit the flock to remain together and lead to communal nesting.

Another bird shows the behavior at the level of *C. major*. In the species *Yukina bruneiceps* (Timaliidae), according to Yamashima (1938), "several pairs of birds join in building one nest." His data for four nests show that four or six birds, laying two or three types of eggs, composed each flock. *Corydon* (de Schaunesee, 1928) may have similar habits. In addition a comparison with the Jackdaw (Lorenz, 1931, 1938) and the Rook (*Corvus frugilegus*) (Yeates, 1934) is instructive. In these species, although there is a colonial territory, the strict maintenance of pair territories has prevented social nesting. Some Magpies (*Pica*) (Linsdale, 1937) live in similar colonies. The Weaver Finch, *Philetarius*, (Friedmann, 1930) nests in colonies and the colony defends a territory. Some colonial birds have no colonial territory, as the Oropendolas (*Zarhynchus wagleri*) (Chapman,

1928). Thus a colonial territory does not necessarily result in communal nesting unless, among other contributing factors, the pair territory is weakened.

At the level of the development of *C. ani* and *C. sulcirostris* the breeding of the California Woodpecker may be mentioned. The woodpeckers live in colonies and several pairs cooperate in excavating a nest hole and raising the young (Leach, 1925; Ritter, 1938). Two Australian genera, *Corcorax* and *Pomatorhinus* (Friedmann, 1925) are reputed to nest communally. Thus at each level in the phylogeny of the Crotophaginae, examples from other groups may be cited, each with a different modification or weakening of the territorialism of the pair.

Breakdown of territorialism in the Crotophaginae

Before analyzing the factors responsible for the breakdown of territorialism within the Crotophaginae, it is desirable to note the assumption that territorialism was originally present in the group. Territorialism is now considered to be a widespread phenomenon in the vertebrate classes. Breder (1936) has summarized the behavior of many fishes (Centrarchidae) and Noble (1938) and Noble and Curtis (1939) have analyzed the relation of sexual selection to territorialism. In those fishes which build nests the male guards the nest site. When the female arrives and copulation occurs, the eggs are deposited. The male in many species guards the eggs and then the young until they are able to fend for themselves. The defence in these species has the characteristics of avian territorial defence and can be differentiated from sexual fighting as such. In the Amphibia data indicate that the male commonly has a calling and mating station but as yet these data are insufficient to be certain that this is analogous to the territories of birds. For lizards the work of Evans (1936, 1937, 1938) and Evans and Clapp (1940) has shown that the species *Anolis carolinensis* maintains a territory in accordance with the characteristics of avian territories. For birds, the evidence is overwhelming that most species are territorial. The reviews of Nice (1933) and Lack and Lack (1933) indicate the extent of the behavior. For the Cuculidae in particular, Makatsch (1937), Friedmann, (1928b) and Davis (1940c) indicate that territorialism is nearly universal within the group. Chance (1922) found that the female European Cuckoo will lay in an unusual fosterer's nest rather than leave her territory. However, there are records of two females using the same territory (Gosnell, 1932). Among the African Cuckoos, Friedmann (1928a) found that many parasitic species have territories which are dependent upon the availability of nests to parasitize. However, *Lampromorpha* has a faulty defence of territory and *Eudynamis* has lost the territorial instinct. Therefore, since territorialism occurs in most other cuckoos, we would seem justified in assuming that it was originally present in the Crotophaginae. The manner in which the behavior patterns of territorialism were weakened and modified may now be considered.

Several factors probably have contributed to the breakdown of territorialism for the pair. The first is that sexual fighting (fighting in relation to the sex-partner) is absent or extremely weak in the whole subfamily Crotophaginae. This situation may have permitted freer relations between the various members of the colony and a loosening of the sexual bond. As to the origin of the lack of sexual fighting it may be suggested that a contributing factor is the habit of living in colonies, thus producing within the group an individual familiarity which precluded sexual fighting. A second factor which contributed to the breakdown of territorialism is the lack of a song. In most territorial birds song is one of the most effective methods of maintaining a territory. None of the subfamily has any note with the characteristics of song. The possession of a song might have prevented the breakdown of territorialism.

Some observations on the defence of the territory deserve mention. According to the concept, the owners drive out birds of the same species. In the case of *C. ani*, other species, such as *Corvus nasicus*, and an entirely black member of the Icteridae (*Ptiloxena*) are driven out on all occasions. The defence of territory against the latter species must not be confused with the act of stealing eggs from the nests. The manner of stealing eggs differs in notes, in flight, and in flock behavior from the act of driving a *Ptiloxena* out of the territory. Although this species is smaller than *C. ani* nevertheless this defence reaction is probably due to an error of identification of the individual. But on the other hand, in British Guiana where *C. ani* is quite as aggressively territorial, *C. major* is permitted to remain in the territory and even sleep within a few feet of some individuals of *C. ani*. *C. major*, to the human observer, more closely

resembles *C. ani* than does *Ptiloxena* yet apparently there is some feature which serves to distinguish the species. Errors of discrimination are common in other species. Song Sparrows (*Melospiza melodia*) (Nice, 1937), Kingbirds (Davis, 1941b), and the English Robin (Lack, 1939a) frequently drive other species out of the territory. In these cases the behavior is considered to be an exaggerated territorialism.

The observance of territorial boundaries differs among various species of birds. Thus, for example, there is variation in the reactions toward a predator. In *C. ani* when a predator (human, cat) comes to the nest tree of the colony the neighboring birds come near, attracted by the alarm call. But these neighbors do not enter the territory of the disturbed group. The attraction of the alarm call does not override the disposition to remain within their own territory. Some other species, as for example the Willet (*Catoptrophorus semipalmatus*) (Vogt, 1938), will go outside a territory and cooperate in the pursuit of an enemy. Fautin (1940) found that the Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*), although strictly territorial, cooperated to drive out predators. L. Miller (1930) found that Horned Owls (*Bubo virginianus*) ignored humans when driving an invader out of the territory.

Biological value of territory

The function or biological value of the territory (as distinguished from the psychological cause of fighting) has been discussed at length in the literature. Food supply is the most obvious function. It has been shown (Davis, 1940a) that in *C. ani* the size of the territory of different colonies which contain the same number of individuals varies greatly in the same ecological habitat. Furthermore, in British Guiana, *C. major* may live within the territory of *C. ani* and certainly is a competitor for food. Food, then, is probably not an essential function of territory but an incidental result among these birds. As a matter of fact no function of territory in these species is clearly apparent other than the primary function, the provision of a mating station and nest site. It must be remembered that the function of territory does vary greatly among various species. As an example of the possibilities of variation in the function of territory, Skutch (1931) observed that in the Hummingbird, *Amazilia*, 50 per cent of the nesting failure was due to the birds stealing material from other hummingbirds' nests. Territorial defense would have prevented this robbery. The function of territory may even change during the year. Thus the Micheners (1935) found that in Mockingbirds (*Mimus polyglottos*) summer territory depended on the nest and was defended only by the male. On the other hand in the winter the male and/or the female may defend a territory for feeding purposes. In January the behavior changes from the winter to summer type of defense. This situation obtains in Shrikes (Laniidae) (A. H. Miller, 1931) and in the English Robin (Lack, 1939a).

These variations in the function of territory emphasize the fact that to be of any value the territorial concept must be sufficiently broad and flexible to describe and integrate the behavior of many species of animals. Meise (1936) shows the great variation in function among different species by classifying territories under various headings: (1) the relation between the size of the territory and area (*Lebensraum*), (2) duration of territory, (3) number of birds using it, (4) biological function. This exhaustive analysis provides a basis for the classification of the territorialism of any particular species. Friedmann (1933) points out that species vary in expressing territorialism in time and space. Both must be considered. As Nethersole-Thompson (1934) suggests, territory operates in relation to the peculiar needs of the species. Even within the same species territorialism may vary. For example, *Larus marinus* (*l. c.* p. 23) is territorial in some areas and colonial in others. Territorialism is a means to success in reproduction and not an end in itself. The study of the nesting habits of the Crotophaginae furnishes further evidence that territorialism is a variable behavior and can not be rigidly circumscribed by a definition if the concept is to have any usefulness. The patent development within one group of closely related species of a colonial territory from a pair territory, emphasizes the usefulness of an inclusive term.

Several attempts have been made to define strictly territorialism. These definitions are not in terms of function. Every definition presents only one point of view and thus automatically excludes many species. The latest attempt is the definition of Lack (1939a) in which he states that territory is an isolated area defended by one individual of a species or by a breeding pair against intruders of the same species and in which the owner makes itself conspicuous. This definition

suffers from the same drawbacks as any definition of territorialism (cf. Davis, 1940a: 206). It is too narrow and excludes too many species from the concept. Colonial birds, such as the Jackdaws, Crotophaginae, Gulls (Kirkman, 1937), and the California Woodpecker are eliminated. Further, it excludes polygynous species such as *Cassidix* (McIlhenny, 1937), Yellow-headed Blackbird (Fauntin, 1940), *Euplectes* (Lack, 1935), and lizards (Evans, 1938). This definition carries with it the tacit exception that an intruder of the same species which is a potential mate is not driven out and further it does not take into account several birds such as the Chickadee (*Penthestes atricapillus*) (Odum, 1941) which defend a territory but do not make themselves conspicuous by song or position. For these reasons it seems preferable to align the concept of territorialism with such concepts as 'species' and not try to define it strictly.

It is desirable to call attention to two principal types of fighting. Fighting in reference to the piece of land (territorialism) is the subject of this discussion. The fighting by the Crotophaginae in reference to the sex-partner has not been discussed here for lack of evidence. This lack is probably due to the masking of sexual fighting by territorial fighting. The behavior of the Crotophaginae shows clearly that the defense of territory is a separate element from sexual fighting. Fighting over the sex-partner does not enter into the motivation. The motivation is the defense of the nest and the piece of land. The whole colony defends the territory no matter what the sex of the defenders or intruders may be. It is becoming clear that the separation of the elements of territorial defense and sexual fighting should have been recognized earlier. The behavior of other species shows clearly that there are several causes of fighting among birds. For success in reproduction there are three principal reasons for defending the nest site: (1) Predators must be driven off; (2) A sex-partner must be secured and defended against other members of the species which attempt to obtain the partner; (3) A spot suitable for pairing, for placing the eggs, and for raising the young must be secured. It is proposed to restrict the term territorialism to the last-mentioned type of fighting. The most important separation is the distinction between fighting over the piece of land and fighting in relation to the sex-partner. As examples in other species, Vogt (1938) finds that in the Willet the defense of territory gradually supersedes the defense of the female as the breeding period advances. Eventually sexual fighting is no longer necessary because territorial defense excludes all males. Defense of territory and of the female are the two causes of strife among Willets and often mask each other. Tinbergen (1939) describes the sexual fighting in the Snow Bunting. After the female arrives fighting increases and the male will fight outside the territory to defend the female. The birds drive away other birds of the same species, but, while the female fights for the male only, the male defends the female and also the territory. In this species territory defense is a behavior of the male only. These considerations demonstrate the variation in the causes of fighting. Territory is a very important cause and has been the subject of this discussion of the Crotophaginae.

It is now important to consider the origin of territorialism. Since the nest is the only factor in the bird's economy which is fixed, it seems likely that the territorial defense originated from the defense of the nest site or mating station. This viewpoint is in agreement with data on other birds and vertebrates. Noble (1940) states that in primitive birds (Night Herons) territories retain their piscine function of being primarily a place where sexual bonds are formed. In fishes (Centrarchidae) the territory is the place where copulation occurs. Secondarily, the territory has become the place where eggs are laid and develop. Hubbs and Bailey (1938) found that the Smallmouthed Black Bass (*Micropterus dolomieu*) defends the nest and that copulation occurs only on the nest. Huxley (1914) found that in Great Crested Grebes (*Podiceps cristata*) coition occurs only on the nest. Venables and Lack (1934), in the same species, observed that territorial behavior is clearly correlated with the position of the nest, and again (1936) that territory is associated with the nesting platform. This situation resembles the behavior of fish greatly. Lack (1939b) states that the function of territory in the Blackcock (*Lyrurus tetrix*) is to reduce the amount of interference between males at copulation. Schuz (1936) studying the White Stork states that "one often has the impression that it is first the nest that is defended and second the mate." Friedmann (1929) found that the Cowbird (*Agelaioides badius*) chooses the nest and then the territory. Also (1928a) he finds that in African Cuckoos territory is dependent upon the availability of nests to parasitize. Nethersole-Thompson (1933) in-

cludes interspecific fighting (for example, the fighting between woodpeckers and starlings for a nest-hole) as territorial. The behavior of these species indicates that the place of copulation (nest-site) is the original territory. But among the data contradicting the view is the fact that many highly evolved species choose territory before the nest. In some cases the female builds a nest outside the territory. Lorenz (1938) believes that the territory of the herons has shrunk to small size. Tinbergen (1935) interpreted his data on Phalaropes (*Phalaropus lobatus*) to indicate that the nest site is not an essential part of territory. Selous (1933) expresses the viewpoint that the territory is symbolical of the female and that the male defends the territory as he would the female. However, this contradictory evidence can be reconciled with the notion that the mating spot is the original territory. A division of nesting activities between the members of the pair can permit great variation in the relations between the mating station (territory) and the nest.

The evidence presented above suggests that the defence of the spot of ground on which sexual bonds can be formed and the nest built is the origin of territory. This viewpoint contains several assumptions. It is assumed that the defense of the piece of land can be extended forward and backward temporally and also can be extended spatially. The forward extension of a behavior pattern is commonplace in the lives of animals. Many species for example, incubate before the eggs are laid (*Ectopistes*, Whitman, 1919). Lack (1940) suggests that feeding the mate during courtship is an extension forward of feeding during incubation. Thus the extension in time of the defense of the nest site and the mating station encounters no difficulties. This viewpoint of the origin also assumes that the bird is able to recognize a potential competitor for the nest site. This recognition permits the explanation of the fact that many species stop active defense of the territory after the nest is built and recognize the territories of other birds by mutual agreement (Nice, 1937). The neighboring birds are known not to be competitors for the piece of land, whereas strange birds are known to be either competitors for the land and/or for the mate.

ABERRANT BREEDING HABITS

As was mentioned in the introduction, the Cuculidae show throughout the entire family a tendency to have unusual breeding habits. In the Crotophaginae these aberrations have developed into communal nesting. This proclivity is presumably based upon some peculiarity of the endocrine system although at present we know practically nothing about what the exact situation could be; nevertheless several conditions may be mentioned.

Presumably birds, like mammals, may be divided roughly according to the spontaneous or non-spontaneous method of ovulation. It is of course clear that the exact meaning of 'spontaneous' breaks down when courtship is considered. In mammals the term refers to species such as the rat, in which ovulation occurs at regular intervals without external stimulation. Other species (non-spontaneous), such as the rabbit, under natural conditions ovulate only after the stimulation of coition. In birds the external stimulation of coition has been superseded by the more intricate courtship performance. In many cases ovulation can be produced by a very slight external stimulus such, for example, as stroking the neck of pigeons. It becomes very difficult then to determine exactly what species are spontaneous and what are non-spontaneous. Marshall (1936) divides birds roughly into two groups in respect to ovulation; those which ovulate spontaneously and seldom mate for life or have elaborate courtship, and the non-spontaneous ovulators which frequently possess elaborate courtship performances. These generalizations do not hold for Parrots, which mate for life and ovulate spontaneously. The Rhea, which is known to have polygynous nesting habits, probably ovulates spontaneously. Harper (1904) suggests that polygynous birds are spontaneous and that monogamous birds are non-spontaneous. Craig (1913) points out the spontaneous (Phasianidae) and the non-spontaneous (Columbidae) types of ovulation. Allen (1925) although not using the terms spontaneous and non-spontaneous, points out the difference in the type of egg-laying as exemplified by the hen and the pigeon. He further suggests that sight of a nest is the stimulus which causes certain wild ducks to deposit eggs. It must be remembered that there are three distinct phases in the production of an egg. The growth of the egg and follicle is the first stage and apparently is under the control of the follicular stimulating hormone (FSH). The actual ovulation is the second stage and is controlled by the luteinizing hormone (LH). The last stage is

the passage down the oviduct and the actual deposition of the egg in the nest. Just what factors influence this last event is not clear at present. The term spontaneous must be used to refer only to ovulation and not to laying.

There is considerable evidence to indicate that the Crotophaginae as well as the rest of the Cuculiformes are spontaneous ovulators. Farley (1924) reports that a pet which lived in his house, dropped eggs frequently on the floor. The birds drop eggs frequently on the ground even far away from the nest. Although Friedmann (1929) found that Cowbirds frequently drop eggs on the ground, in this case these aberrations are probably the result of social parasitism. The habit of spontaneous ovulation in the Crotophaginae is closely related to the lack of courtship performance. Since the function of courtship behavior is, primarily at least, the stimulation of ovulation, spontaneous courtship and lack of courtship are compatible. In birds such as the Crotophaginae which ovulate spontaneously there is no need or use for courtship. On the other hand, in those species which ovulate non-spontaneously, courtship display does have a use in identifying the sexual ripeness of the individual. Thus Noble (1938) found that in many fishes the display was a means of identifying not the sex but the sexual ripeness of the individual. A further development of this condition is the use of display to stimulate and synchronize the sexes, as Carpenter (1933) found in the pigeons. Huxley (1916, 1921) has suggested that the function of courtship is not selection of a mate but stimulation to copulation. In animals with courtship performances the external stimulus releases the internal endocrine mechanism responsible for ovulation. Craig (1911) found that the pigeon, which normally ovulates after courtship and is considered to be non-spontaneous, will ovulate even if there is no male present, but under these conditions only late in the season. Virgin females may not lay at all without a male. On the other hand, in animals which ovulate spontaneously, the stimulus to ovulation is brought about by an automatic release of the endocrines responsible for it independent of external stimuli. Courtship thus appears to be an external regulator superimposed upon the internal processes.

As a further correlate of spontaneous ovulation and the lack of courtship may be mentioned the lack of pair formation. Courtship, especially mutual post-ovulatory performances, serves to bind the members of the pair together in some species and to prevent the dissolution of the couple. The courtship performances, either by one of the pair or by both birds, serve to maintain the pair. Thus, in the Crotophaginae, the lack of bonds between the members of the pair and spontaneous method of ovulation are contributing factors permitting communal nesting. It should be emphasized that it is not intended to imply that spontaneous ovulation must necessarily be followed by communal nesting but that spontaneous ovulation permits the lack of courtship and of the bond between members of the pair, thus making possible and contributing to the development of social nesting.

Parenthetically it should be noted that many birds with most elaborate courtship (game birds, birds of paradise, mankins, hummingbirds) do not pair. In these groups the elaborate courtship is necessary to induce copulation.

Number of eggs laid

The two types of ovulation, spontaneous and non-spontaneous, exemplify one phase of the general problem of internal and external control of a neuro-endocrine mechanism. As background for a discussion of another phase of this problem, it is desirable to discuss the number of eggs laid by each female. In both genera of the Crotophaginae the number laid by a female is usually six, although sometimes it is five or seven (cf. Davis, 1940a, 1940b, 1941a). Skutch (Bent, 1940) believes that *C. sulcirostris* lays four eggs, a figure probably too low. Since several females lay in the nest there may be great variation in the number of eggs deposited in one nest. Thus the number of eggs laid by one female cannot be determined by the number in the nest. The number laid can be determined, however, by microscopic examination of the ovaries. The fact that a constant number is laid would suggest that the size of the clutch is fixed by an internal endocrine mechanism. The evidence as reported by Farley (1924), whose pet bird laid eggs for a long period of time, is not described in sufficient detail to be of value in this connection.

That there can be a difference in the method (external or internal) controlling the production of eggs is shown by the consideration of the factors which determine the number of eggs laid. Some birds lay until there is a certain number of eggs in

the nest. The Flicker as reported by Phillips (1887) is the classic example. If eggs are removed from the nest this bird continues to lay until, in one case, as many as 73 eggs have been deposited, although it is possible (in litt.) that several females laid in this one nest. Other species lay only a certain number no matter how the number of eggs in the nest may be manipulated (Davis, unpub., *Larus argentatus*). Craig (1913) recognized these two types of birds and pointed out the Flicker and the pigeon as examples. In the first type (which the author suggests be called indeterminate) the external conditions determine the number of eggs laid. In the second type (determinate) the number is fixed by the internal hypophyseal-ovarian mechanism. The observations of Hann (1937) that in Ovenbirds (*Seiurus aurocapillus*) brooding began after laying the penultimate egg even though 3, 4, 5, or 6 eggs were laid in the clutch, suggests that the brooding impulse may regulate the number of eggs laid. The fact that the Flicker has elaborate courtship (Noble, 1936) suggests that in this species ovulation is non-spontaneous. At present, knowledge is insufficient to state certainly that indeterminate egg-laying is found in birds which ovulate non-spontaneously and that determinate egg-laying occurs in those which ovulate spontaneously.

It is of interest that another bird in which communal nesting has developed, the California Woodpecker, belongs to the Picidae which are prolific egg-layers. The classical example of the Flicker which laid 71 eggs in 73 days shows to what extent the birds can lay eggs. Eggs of various woodpeckers are frequently found in the nesting holes of other birds, and the group as a whole is famous for laying a varying number of eggs. The ducks are also prolific egg-layers and frequently lay in other birds' nests. Allen (1925) has indicated the importance of this habit in the eventual culmination of parasitism in the South American duck *Heteronetta*. Friedmann (1932) lists many species of ducks which have laid eggs in the nests of other species.

The above discussion is concerned with one aspect of the general problem of the interrelations between the nervous and the endocrine systems, namely, the internal or external regulation of the hypophyseal-ovarian mechanism. Another problem concerning the breeding and the relations of the gonads to the nervous system is the fact that, in *C. ani* and others of the subfamily, incubation by several females starts simultaneously. The individual bird, however, may not have completed its clutch or may have finished laying several days before. It should be noted, however, that in most cases incubation does not start until a few days after the egg-laying has stopped. It seems that continued egg-laying by one bird inhibits the incubation by the other birds. Possibly imitation may be the reason the birds, which have completed ovulation some time previously, start to incubate. It is known in general that the behavior of a bird towards the contents of the nest is dependent upon the contents and can be changed radically by changing the contents of the nest. For example, the substitution of eggs caused *C. ani* to brood for 24 days although the normal length of incubation is about 13 days. A Robin (*Turdus migratorius*) will feed young which are substituted for newly-laid eggs (Davis, unpub.). Contrasting with these species are others which have a fixed duration for each phase of the breeding cycle. Thus the Noddy Tern (*Anous stolidus*) (Watson, 1908) did not change behavior when chicks were substituted for eggs. Apparently this is a species difference in the control of behavior by external and internal stimuli.

Unusual aspects of reproduction

A further factor of unknown significance to the breeding habits is the fact that the Crotophaginae have a continuous molt. In general birds molt just before and/or after the breeding season. It is known that this molt is connected with the endocrine system in several respects. Just what connection, if any, there may be between the continuous molt and the endocrine situation in the Crotophaginae is not clear. It should be noted that other birds such as the Ptarmigan (Salomonsen, 1938) have a continuous molt. The observations of the Micheners are of interest in connection with the loss of territorialism as correlated with the molt. These investigators found (1935) that the Mockingbirds maintain territory throughout the year but that there is a slackening of territorial defense during the molt. The English Robin maintains a territory except during the molt (Lack, 1939a).

A word of caution is necessary. Endocrinology is not a panacea for the explanation of all sexual behavior. The task is to find out what relations exist. For example, Lack (1939a) finds that the English Robins establish territories and select

mates in the fall when the gonads are regressed. This indicates that the gonadal hormones at least are not responsible for these particular behavior patterns or that estrin inhibits territorialism in the female when this hormone appears in the spring (cf. plumage in chickens, Domm, 1939). A further complication is the common occurrence of song in the fall. Brewster (1898) observed several species of swallows attempting copulation and carrying mud on August 22, after the migratory flock had formed. These examples indicate the magnitude of the task.

Aberrant breeding habits are frequently connected with an abnormal sex ratio in the population (Mayr, 1939). In fact when there is an unusual sex ratio, unusual nesting habits may be suspected. In the Crotophaginae the sex ratio is greatly in favor of the males. The question now arises as to whether the breeding habits are the result of an altered sex ratio or the converse. Sarasin (1924) believes that polyandry is the cause of social parasitism in the Cuckoos. As to the actual reasons for the abnormal sex ratio we know nothing positively although many hypotheses have been suggested.

As a manifestation of abnormal breeding habits a consideration of the frequency of feeding the young is of interest. In *Guira* the young are fed at long intervals, seldom less than one-half hour (Davis, 1940b), but in *C. ani*, although each individual bird comes to the nest only at long intervals, since several birds are carrying in food the young are fed fairly frequently. Compared with other birds, Herrick (1910) found that young American Cuckoos (*Coccyzus*) were fed every 25 minutes and sometimes as often as every four minutes. Passerine birds sometimes are fed at much shorter intervals. Baldwin and Kendeigh (1927) found that a female House Wren (*Troglodytes aedon*) fed the young 18 times in 34 minutes. Bigglestone (1913) found that Yellow Warblers (*Dendroica aestiva*) fed the young over a period of ten days more than 16 times per hour. In the Crotophaginae in addition to the factor of the infrequent feeding is the fact that not all the females incubate even though they may have laid eggs. These facts all indicate a most casual care of the young birds. Neither is the behavior of the adult birds at the nest highly developed. There is no ceremony at the nest at the exchange of incubators or at feeding. The adults do not carry away the egg shells or excreta from the nest. In some Cuckoos (Herrick, 1910) the adults await the defecation and then remove or eat the fecal sac. No such behavior exists in the Crotophaginae. The excreta are not even contained in a sac.

The analysis of the factors responsible for the construction of abortive nests and the performance of symbolic activities is pertinent to the problem of aberrant breeding habits. It has been shown for *C. ani* that, at the first part of the season, many nests are started and then neglected. The usual explanation of this type of behavior is that the bird's reactions are not yet of sufficient intensity; a statement which explains nothing. Tinbergen (1939) describes these behaviors as "unfinished actions so typical of maturing instinctive behavior." That there can be a lack of adequate stimulus for the completion of a nest is shown by the work of Ali (1930) on a Weaver Finch (*Ploceus philippensis*). He found that the number of females per male in this polygynous species depends on the number of nests the male can build. At the end of the season many cock nests are built by males whose 'zeal' is insufficient to finish the nest. But on the other hand, it must be remembered that in many cases the abortion of a nest may be caused by the lack of a suitable location. Bennett (1938) found that female Blue-winged Teal (*Querquedula discors*) inspected many nesting sites before selecting a suitable location. Abortive nests were frequently started in unsuitable locations—as generally occurs in the duck family.

The question of mutual stimulation among members of the flock must be considered in relation to the egg-laying and the abortion of nests. This hypothesis has been developed by Darling (1938) to explain the behavior of groups of gulls. His evidence indicated that reciprocal stimulation among the members of the flock was conducive to greater success in nesting. In the flocks of Crotophaginae, mutual stimulation may be important in the stimulation of egg-laying and incubation, although the data do not show that large colonies were more successful than small ones. Other species show stimulation by the group. Lack and Emlen (1939) found that all birds in a colony of Tricolor Redwings (*Agelaius tricolor*) are in the same state of breeding. But nearby coloneis may differ greatly in their respective stages of breeding. Hoogerwerk (1937) found that the White Ibises, which nest in groups on a platform, were in the same stage of nesting on each platform. Appar-

ently courtship (in the broad sense) can be effective beyond the actual mate.

TYPE OF HABITAT

The importance of the influence of the habitat on the development of social nesting habits is difficult to assess. *Guira* inhabits areas of open park-land savanna and sleeps in clumps of dense trees. Also, the birds tend to nest in thickly foliaged trees. Since there are not many groups of such trees the tendency is for the birds to come together in flocks. The original habitat of *Guira* was probably the Chaco and the campos of Brazil. These areas are characterized by open stretches of grass or marsh with scattered clumps of trees. The birds, able to feed out in the open, are thus forced to come together to sleep and nest. Although these islands of trees sometimes are very large, nevertheless there is the tendency for the birds to gather together. It seems likely that the flock habit developed in part under the influence of the habitat. It is of interest that the California Woodpecker, another species with comparable habits, also occurs in areas where the vegetation is distributed in islands. Ritter (1938) states that this woodpecker inhabits forest islands and that the boundaries of the island limit the area of one group of birds.

Crotophaga major and *C. ani* also inhabit more or less open areas, although they return to trees for sleeping and nesting. *Major* is frequently found along the forest edge but never in the thick forest. It lives along the borders of streams, probably because of the nature of the food. Both *Guira* and *C. ani* inhabit mesic habitats. The latter is strictly a moist habitat bird; in Cuba, in the dry season, the birds are found only along the streams, and in Argentina the birds stay throughout the year along streams. The habit of feeding in more open areas and of sleeping and nesting in a clump of trees, presumably developed by the ancestral birds and still to be observed in the primitive *Guira*, has been retained by the genus *Crotophaga*. These considerations suggest the conclusion that the type of habitat in which the species originated and the tendency to divide the territory into a nesting and a feeding habitat have been factors conducive to the development of social nesting.

The habit of sleeping in large flocks occurs in other species, as, for example, *Molothrus* and *Muscivora* as reported by Davis (1940b). In these species, however, there has been no factor conducive to the breakdown of territorialism and no social behavior has developed. Friedmann (1935) points out that colonial nesting persisted in, or developed in, those species which use separate feeding and nesting ground. When the same ecological habitat is used for both feeding and nesting, colonial nesting does not usually develop. Many species have the territory divided into two distinct parts. A. H. Miller (1931) found that shrikes had a definite headquarters in their territory where the birds slept. Mayr (1926) found that a finch (*Serinus*) used different associations for various purposes such as living, dancing, and feeding. Steinbacher (1939) found that Gallinules (*Gallinula chloropus*) defended a resting place, pairing territory, and a nesting territory. Pettingill (1936) found that the male Woodcock (*Philohela minor*) inhabited the woods in the daytime and the fields at night. These selected examples show that the ecological separation of the territory into several parts is a common occurrence among birds.

PHYLOGENY OF BEHAVIOR

The phylogenetic development of the flock habit is clearly shown by the behavior of the four species of the Crotophaginae. As mentioned in the introduction, *Guira* is the most primitive member of the subfamily both anatomically and behavioristically. *C. major* is the next in the phylogenetic scale. *C. ani* and *C. sulcirostris* resemble one another and represent the climax of development. In *Guira* the flock is a loosely coordinated group of birds, feeding in the same vicinity, sleeping together and, although frequently nesting in pairs, regularly nesting communally. In *Crotophaga major* the flock is more united and always nests communally, although pairs which live singly may nest singly. The flock behavior reached the climax in *C. ani* and *C. sulcirostris*. In these species the group lives together in a closely-knit organization and nests communally. It is of interest to contrast this behavior with that of other flocking species, such as the Oyster Catcher (Huxley, 1925). In this species pairs leave the flock to go to the breeding territory for a while and may collect in flocks until the eggs are laid. But the strict maintenance of territorial boundaries prevents the encroachment by the flock upon the territory of a pair. Hence social nesting is impossible.

The breakdown and redevelopment of the territorial behavior is also a phylogenetic trend. In *Guira* the defense of the territory by the pair is weak and that by the colony is also weak. In *C. major* the defense of a colonial territory is positive but nevertheless not vigorous. In *C. ani* the defense of the territory by the whole colony is fierce and effective and pair territory has vanished.

This summary of the phylogeny of territorialism in the Crotophaginae suggests the consideration of the relation of this subfamily to the development of parasitism in the other Cuculidae. Herrick (1910) suggests that a maladjustment of the nest-building and egg-laying results in parasitism—a statement which is an outline of the problem but not a solution. Allen (1925) emphasizes the fact that no one theory should be expected to account for the development of the several types of parastitism. He further outlines the distinction between egg-parasitism and nest-parasitism. This scheme has been verified by subsequent research and is followed in this paper. The cuckoos and ducks (egg-parasitism) developed parasitism by dropping eggs occasionally in the nests of other birds, although also building their own nests as, for example, in the Redhead (*Nyroca americana*). On the other hand, the Cowbirds (nest-parasitism) developed parasitism by stealing the nests of other birds or using old nests. The latter trait is common in the Mourning Dove (Nice, 1922) and habitual in the Solitary Sandpiper (*Tringa solitaria*). In these species certain behaviors (regurgitative feeding, precocial habits) precluded the development of parasitism. Davis (1940a) strongly supports these ideas. Friedmann (1928b) accepts this suggestion as a partial solution for Cowbirds. In addition, he emphasizes, there must be a loss of territorialism.

The evidence from the phylogeny of the Crotophaginae indicates that the Cowbirds and the Cuckoos have in common the modification of territorialism but that the other patterns of behavior in the species precluded the identical development of the habit. In the Cuculidae the courtship is weak or absent and the ovulation is spontaneous. Territorialism is retained in a much modified form but the spontaneous ovulation permits the laying of eggs in other birds' nests. From occasional laying in other nests some species developed the habit of always laying parasitically. That the tendency to lay eggs promiscuously occurs in nonparasitic members of the family is shown by the fact that Pemberton (1925) found the egg of a *Geococcyx* in the nest of a raven; he wrongly interprets this occurrence as deliberate parasitism. In the Cowbirds, in contrast to the Cuckoos, the courtship is retained and elaborated and ovulation is probably non-spontaneous. In these species the usurpation of a nest is necessary when the birds do not build their own nests. From the usurpation of a nest it is an easy step to laying in the nests of other species. These Cowbirds have developed parasitism in a very different manner and even the result, although superficially very similar, is different in many details.

The place of the Crotophaginae in the phylogeny of the parasitic cuckoos is worth consideration. Makatsch (1934) believes that the Crotophaginae represent a stage in the development of parasitism; that after a communal nesting habit, the next stage is true parasitism of other species. The evidence presented in this paper shows that the Crotophaginae represent not a stage in the development but an offshoot. Daguerre (1924) suggests that communal nesting developed as parasitism of one pair on the other. This would assume that there occurred the development of two phases within the species; one parasitic and the other non-parasitic. The fact that in some cases all birds take part in incubation and feeding precludes this interpretation.

The consideration of the phylogeny of behavior and the relation to parasitism in general suggest the desirability of a few inferences as to the future of the group Crotophaginae. At the present time the group seems to be at the climax of possible development. The species are universally successful as is shown by the fact that they are among the most abundant birds in their range. Low temperature seems to be the only barrier to their distribution. Their social habits help the individuals to avoid enemies. Nevertheless one purely hypothetical course of evolution is open to the group. It has been found that the birds are extremely indolent in their attentions to the nest. Individuals which laid eggs did not incubate. Birds which incubated did not feed the young. It is possible that a parasitic phase could develop within the species. Those individuals which lost the instinct of building the nest could survive by laying in the nest built by others. Thus a parasitic phase might develop. If this phase should evolve some morphological characteristic we

should then have the evolution of a new species—perhaps the evolution of two new species. In this connection it should be remembered that many of the parasitic birds (Cowbirds, Viduinae) parasitize closely related species. It is, however, not intended to suggest that all these actually did develop parasitism in exactly this manner.

Summary

The Crotophaginae, one of the six subfamilies of Cuckoos, demonstrates the phylogeny of communal nesting. The birds live in flocks and build one nest in which several females lay eggs. The subfamily consists of four species, distributed throughout South and Central America. The development of social nesting occurs at three levels, represented by the species: I. *Guira guira*, II. *Crotophaga major*, III. *C. ani* and *C. sulcirostris*. The primary factors conducive to the development of social nesting habits are (a) modification of territorialism, (b) aberrant breeding habits, and (c) the type of habitat.

During the investigation the behavior of *Crotophaga ani* was found to be essentially identical in three widely separated localities; Cuba, British Guiana, and Argentina. The call notes of the members of the subfamily are similar as well as other behavior patterns. Some evidence concerning the problems of discrimination of the sex-partner, of the individuals of the species, and of the boundaries of the territory was obtained. The sex-partner and other individuals of the flock are recognized by individual appearance. Strange birds probably are first discriminated by their behavior and then by appearance. The boundaries of the territories are known exactly by the trees and shrubs. Some of the behavior patterns exhibited by the species may be classed as releasers or sign-stimuli. Thus the birds gave the same response to an injury-feigning dove as to an injured member of their own species.

Each flock of all four species maintains a territory. However, the details differ in each case. *Guira* defends the territory only slightly and frequently one pair builds a nest and defends a small territory within the territory of the flock. The flock of *C. major* is composed of pairs which unite to defend a territory. Thus the colony is really a group of pairs which cooperate to build one nest. In *C. ani* the communal nesting has reached its climax. Polygamy or promiscuity is the general rule and the whole colony defends the territory. This phylogenetic development of social nesting coincides with the disappearance of territorial defense by the pair and the appearance of territorial defense by the colony. Several factors have contributed to the breakdown of territorialism for the pair. Sexual fighting is weak or absent. There is no song in any of the species. Courtship performances are lacking or simple. In these species the biological value of the territory is probably merely the provision of a mating station and nest site. The obvious development, within one group of birds, of a colonial territory from a pair territory, suggests the usefulness of an inclusive, flexible characterization of the term territorialism instead of a strict definition. The behavior of the Crotophaginae further shows that sexual fighting (in reference to the sex-partner) must be clearly separated from territorial fighting (in reference to a piece of land). Territorialism probably originated from the defense of a spot of land on which the sexual bonds can be formed and the eggs laid.

The aberrant breeding habits of the various species permitted the development of social nesting. Several minor factors are of interest. The species have a continuous molt. The sex ratio is in favor of the males. The birds are indolent in the care of the nest, feeding the young at long intervals, and incubating sporadically. Many abortive nests are started and many eggs dropped on the ground or laid in the nest before completion of construction. The important factor is that the Crotophaginae, judging by indirect evidence, ovulate spontaneously and thus do not require courtship performances and pair formation for successful laying. This spontaneous ovulation raises the general problem of internal and external control of a neuro-endocrine mechanism. As one example the data indicate that members of the subfamily lay six eggs normally, therefore the hypophyseal-ovarian mechanism is set to lay a fixed number of eggs no matter how many are in the nest.

The third factor conducive to the development of social nesting habits is the type of habitat. The original habitat was probably a region containing scattered clumps of trees, such as the Chaco or the campos of Brazil. The birds are thus forced to come together to sleep and nest in the trees. This primitive habit is retained in the more evolved species of the subfamily which use different parts of the territory for feeding and nesting.

This subfamily of Cuckoos has developed the social nesting habits, in contrast to the parasitism evolved by the other Cuckoos. Social nesting, however, is probably not a stage in the development of parasitism but a side branch in the evolution of a peculiar nesting habit.

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THE INNERVATION OF THE ADRENAL GLAND

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I. THE GROSS ANATOMY OF THE NERVE SUPPLY TO THE ADRENAL GLAND

THE adrenal gland has associated with it a preponderance of nervous tissue which seems far in excess to that which so small a structure might require. This apparent redundance of nervous tissue can be explained on the basis of two factors. The first of these is most likely related to the ectodermal origin of the medulla. The idea that the adrenal medulla is capable of giving rise to efferent impulses, and thus act as a sort of peripheral nervous center, was proposed by Jacobj (1892), Elliott ('13), Kolmer ('18), and Crile ('31). Rindt and Kahn ('29) could not, however, confirm the findings of the above-mentioned investigators on the neural transmission of adrenalin-invoked impulses. The second of the two factors referred to above is related to the juxtaposition of the adrenal glands to the coeliac plexus. A great portion of the nervous tissue lying in proximity to the adrenals is actually distributed to other organs.

The accepted classification of the autonomic nervous system into sympathetic and parasympathetic divisions will be employed. Though for gross anatomical purposes the splanchnic nerve will be classified as sympathetic, the work of Kure and his many co-workers ('28, '30, '31a, '31b, '31d) on the spinal parasympathetic nerves indicates that this nerve contains parasympathetic as well as sympathetic fibers. Hinsey ('33), in the cat, could not, however, confirm the presence of efferent parasympathetic fibers in the dorsal spinal roots, as maintained by Kure. Nor could Hollinshead ('36) find any degeneration in the splanchnic nerve after sectioning the dorsal roots of the lower thoracic and upper lumbar nerves proximal to their ganglia.

The coeliac plexus (through which the adrenal receives most of its nerve supply) is commonly referred to as sympathetic in nature. In reality it consists of an admixture of parasympathetic (vagus and Kure's spinal parasympathetics) as well as sympathetic elements. Though the vagus fibers enter the coeliac plexus, they have no functional relationship to the ganglia located therein (Kuntz, 1938). It is because of the sympathetic nature of the coeliac ganglia that the other constituents of this plexus are often erroneously referred to as being entirely sympathetic in nature.

The adrenal plexus is referred to as an offshoot of the coeliac plexus. Superiorly the adrenal plexus is continuous with the inferior phrenic plexus, while inferiorly it joins the renal plexus and also the internal spermatic or ovarian plexus on the left side. These gross anatomical features (Fig. 1) have recently been illustrated in detail by Teitelbaum ('33) on the basis of microscopic dissections in infants. The fibers which make up the adrenal plexus are derived from the splanchnic nerve, the sympathetic trunk, the coeliac ganglion, the vagus nerve, and sometimes the phrenic nerve.

A. The sympathetic nerve supply to the adrenal gland

In contradistinction to its parasympathetic nerve supply, the adrenal gland receives a sympathetic nerve supply, which has its origin in the lower thoracic segments of the spinal cord and traverses the splanchnic nerves and sympathetic trunks to enter the abdomen. The splanchnic nerves make up the more important sympathetic pathway to the adrenal gland. Kure's spinal parasympathetic components of the splanchnic nerve should be kept in mind, however.

The greater splanchnic nerve is generally described as having its origin from about the fifth to the tenth thoracic sympathetic trunk ganglia. Swan (1834), in his detailed anatomical study of the nervous system in man, found the origin of the splanchnic nerve on the right side to be the fifth, seventh, and eighth thoracic trunk ganglia; while on the left side it arose from the fifth to the tenth ganglion inclusive. The lesser splanchnic nerves both arose from the tenth ganglia. Kuntz ('29) states that "the greater splanchnic nerve is formed by the union of several rami arising from the sympathetic trunk between the fifth and ninth or

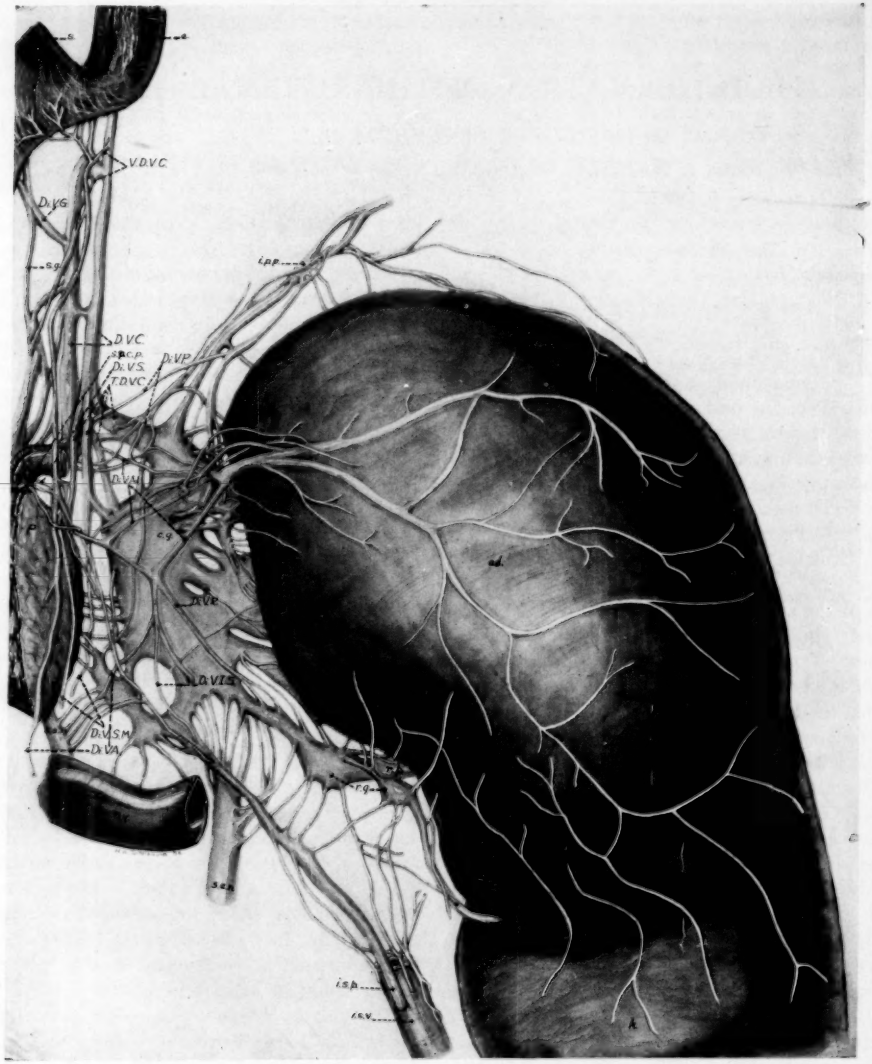

FIG. 1. THE VENTRAL ASPECT OF THE LEFT SUPERIOR QUADRANT OF THE ABDOMINAL CAVITY OF A MALE INFANT

The stomach is rotated to the right on the longitudinal axis of the esophagus, and the tail of the pancreas and splenic vessels have been resected to expose the coeliac plexus and show its relation to the posterior vagus cord and its branches. (The titles of the vagus elements are capitalized.) ad., adrenal gland; cg., coeliac ganglion, left; D.V.C., dorsal vagus cord; Di.V.A., direct vagus rami to aortic plexus; DiV.Ad., direct vagus rami to left adrenal gland; Di.V.G., direct vagus gastric rami; Di.V.I.S., direct vagus ramus to the internal spermatic plexus; Di.V.P., direct vagus ramus to inferior phrenic plexus; Di.V.R., direct vagus ramus to renal plexus; Di.V.S., direct vagus ramus to splenic plexus; Di.V.S.M., direct vagus rami to superior mesenteric plexus; e., esophagus; i.p.p., inferior phrenic plexus; i.s.p., nerves to left internal spermatic plexus; i.s.v., internal spermatic vein; k., left kidney with capsular nerves; p., pancreas (Tail resected); r.g., renal ganglia; r.p., renal plexus; r.v., renal vein; s., stomach; s.a., splenic artery; s.a.n., sympathetic nerves to aortic plexus; s.g, sympathetic gastric nerve; s.p.c.p., splenic plexus contribution to anterior coeliac plexus; T.D.V.C., Terminal branches of dorsal vagus cord; V.D.V.C., Ventral branches of dorsal vagus cord. (From H.A. Teitelbaum., *Anat. Rec.*, v. 55, p. 297, 1933. By courtesy of the Wistar Institute of Anatomy and Biology.)

tenth thoracic ganglia." The lesser splanchnic nerve arises from the ninth and tenth ganglia; while the lowest splanchnic arises from the last thoracic ganglion or from the lesser splanchnic nerve.

Recently Edwards and Baker (1940) studied the variations in the formation of the splanchnic nerves in 100 cadavers. The greater splanchnic nerves were present bilaterally in all instances and varied in origin from the fourth to the twelfth thoracic sympathetic ganglia. The most frequent origin was the seventh, eighth, and ninth ganglia. Only 9 per cent of the cases complied with the typical text book picture. The lesser splanchnic nerve was present on the right side in 93 per cent and on the left in 98 per cent of the cases. They varied in origin from the seventh to the twelfth thoracic sympathetic ganglia but arose most frequently from the tenth and eleventh ganglia. Only 5.5 per cent of the cases complied with the text book picture. The least splanchnic nerve was present on the right side in 89 per cent of the cases and on the left side in 96 per cent. The origin varied from the eleventh and/or twelfth ganglia, the latter being the more common. The text book picture was complied within 82.5 per cent of the cases.

Hollinshead ('36) and Hollinshead and Finkelstein ('37) presented evidence that the adrenal nerves in the cat arise from the lower thoracic and upper lumbar spinal nerves. Swinyard ('37), also in the cat, observed that the last few thoracic spinal nerves give rise to the fibers that supply the adrenal gland. That these nerves are not afferent in nature was demonstrated by Elliott ('13) who excised the dorsal root ganglia of the 5, 6, 7, and 8 thoracic nerves without resulting degeneration of the adrenal fibers. According to Hollinshead, the majority of the adrenal fibers pass to that gland through the lesser splanchnic nerve and the upper lumbar sympathetic chain. Maycock and Hislop ('39) disagree with Hollinshead. The former claim that most of the adrenal secretory fibers traverse the greater and lesser splanchnic nerves. Physiologically, Tournade ('25a, '28) has established the presence of adrenal secretory fibers in the anterior roots of the fourth thoracic to the first lumbar nerves. Young ('38–'39) demonstrated that adrenal fibers leave the cord from segments D6 to L3, with a few fibers from higher and lower fibers in some cases. There was no evidence of contralateral innervation. There is a segmental innervation of the medulla, with the front end receiving fibers from the more superior roots. Section of the great splanchnic nerve caused degeneration in the anterior half of the medulla.

After piercing the diaphragm, the splanchnic nerves terminate in relation to the coeliac plexus. The greater portion of the efferent fibers in the splanchnic nerves are myelinated, preganglionic fibers which pass to the coeliac ganglion where they have their synapses. The adrenal gland, however, in addition to receiving sympathetic fibers from the coeliac ganglion, also receives direct splanchnic nerves which do not have any synapse in the coeliac or any other intercalated sympathetic ganglion. Noellner (1869), in the dog, and Jacobj (1892), in the dog and rabbit, observed and illustrated branches which passed from the splanchnic nerve directly to the adrenal gland. Biedl (1897) also observed that the splanchnics gave off definite fibers which passed to the adrenal glands without first traversing the coeliac plexus. Biedl names these fibers "Rami suprarenales," and he demonstrated the rôle that they play in the physiology of the adrenal gland. Anatomical verification of Biedl's Rami suprarenales is also offered by Renner ('14, '31) and Hirt ('24). The latter illustrated these fibers in the rabbit and in man.

The credit for actually establishing the directness of the above-mentioned adrenal fibers experimentally apparently goes to Elliott ('13). On sectioning the splanchnic nerve in the cat Elliott found that the myelinated nerves in the adrenal gland degenerated to their terminations in the medulla. Therefore Elliott concluded that the chromaffine cells are innervated directly and not through the intermediation of an intercalated neurone as is usually the case. Elliott's conclusions were confirmed by Hoshi ('27), Hollinshead ('36), and Swinyard ('37).

Goloube (1934) showed in the human embryo that the adrenal is innervated by the preganglionic fibers of the great splanchnic nerve during the course of development. These branches go either directly to the adrenal or they traverse the "solaire" ganglia without interruption. Also Goloube (1936) demonstrated in the chick embryo that the penetration of the sympathetic cells, which make up the medulla, by the preganglionic sympathetic fibers occurs simultaneously with the development of chromaffine substance.

In his studies on diuretin glycosuria, Nishi ('09) offers some physiological evidence to show that the left splanchnic nerve transmits impulses to the right adrenal gland, but Hoshi ('27) and Young

('38–39) could not confirm Nishi's observations. After section of the left splanchnic nerve in the rabbit, Hoshi found that while the nerves in the left adrenal medulla degenerated, the nerves in the right adrenal medulla remained quite normal.

In addition to the fibers from the splanchnic nerves and the coeliac ganglion, the adrenal gland also receives a nerve supply from the lumbar sympathetic trunk, according to Elliott ('13), Hollinshead ('36), Young ('38), and Maycock and Hislop ('39). Though the nerves to the adrenal from the coeliac ganglion are not entirely sympathetic in nature, they will be considered as a whole here. When the parasympathetic nerve supply to the adrenal gland is described the vagus constituents of these adrenal nerves will be differentiated from the sympathetic elements.

The various nerves which pass to the adrenal gland go to make up the adrenal plexus. Though the pattern of this plexus is variable in certain details, as in the number of nerves constituting it and in the degree of anastomosis among these nerves, in a general sense its configuration is more or less uniform. This is indicated by a study of the illustrations and descriptions of various anatomists: Walter (1783), Swan (1834), Nagel (1836), Moers (1864), Alexander (1892), Jacobj (1892), Renner ('14, '31), Schkawera and Kusnetzow ('23), Hirt ('24), and Teitelbaum ('33). There is most agreement on the relationship between the adrenal plexus and the renal and inferior phrenic plexuses, as well as on the contributions from the splanchnic nerves. There is extreme variation in the depiction of a capsular adrenal plexus. Swan (1834) fails to show such a plexus in man, while Teitelbaum ('33) illustrates a rather extensive one (Fig. 1) with relatively few anastomoses in the human infant. Many nerves pierce the adrenal parenchyma directly. Undoubtedly the capsular plexus may be either present or absent.

Hirt ('24) observed contributions to the right adrenal gland from an "epiphrenic" ganglion in man. This epiphrenic ganglion, which receives fibers from the coeliac ganglion and which contributes fibers to the diaphragm in addition to the adrenal, is most likely an aberrantly located piece of the coeliac ganglion. Small microscopic ganglia have been observed in the fibers of the adrenal plexus by many of the above-mentioned investigators. Also, according to Moers (1864) and Alexander (1892), the phrenic nerve contributes fibers to the adrenal plexus.

B. The parasympathetic nerve supply to the adrenal gland

Before describing the actual distribution of the vagus fibers to the adrenal gland, it is important to consider certain pertinent facts with relation to the thoracic course of the vagi. From the descriptions offered in certain anatomy texts, as recently pointed out by Teitelbaum ('33), and as is evident in Laterjet and Rochet ('23), Braus ('24), Robinson ('25, '31), Laterjet (30), Huber (30), and still others not mentioned here, one gets the impression that each vagus nerve passes through the thorax and reaches the abdomen as a distinct entity. It is a generally accepted anatomical fact that inferior to the pulmonary roots, the two vagi take up certain positions in relation to the anterior and posterior walls of the esophagus. According to the above-mentioned texts, the right vagus enters the abdomen on the posterior aspect of the esophagus, and the left vagus on the anterior aspect of the esophagus. Though the above is in compliance with embryological data, Arey ('30), there is sufficient anatomical evidence to indicate that the vagus nerves at the level of the diaphragm can no longer be correctly considered as right and left respectively in the same sense that they are so called in their course superior to the roots of the lungs. On the basis of dissections and degeneration experiments, it has been definitely established by Swan (1834), Kollman (1860), Jacobj (1892), Wertheimer ('01), Iwama ('25), McCrea ('25), Brauecker ('27), Uchida ('28), Teitelbaum and Uhlenhuth ('32), and Teitelbaum ('33) that caudal to the roots of the lungs each vagus nerve contributes fibers to both the anterior and posterior surfaces of the esophagus to make up the anterior and posterior esophageal plexuses respectively. At the inferior ends of these plexuses, the vagus fibers converge to form two trunks or cords, the anterior and posterior vagus cords (Fig. 2), each lying on its respective surface of the esophagus. Each of these cords, because of the anastomoses which occur in the esophageal plexuses, contains fibers derived from both the right as well as from the left vagus nerve. In experiments carried out in cats, Teitelbaum (unpublished) has been able to verify the findings of Iwama ('25) with relation to the presence of Marchi bodies in both the anterior and the posterior vagus cords after section of either the right or left vagus nerve in the neck.

Though it has been pointed out above that a

number of contemporary texts of anatomy do not describe the distribution of the vagi accurately, as well as anatomical importance is the fact that Vesalius (1725) fails to depict the intervagus

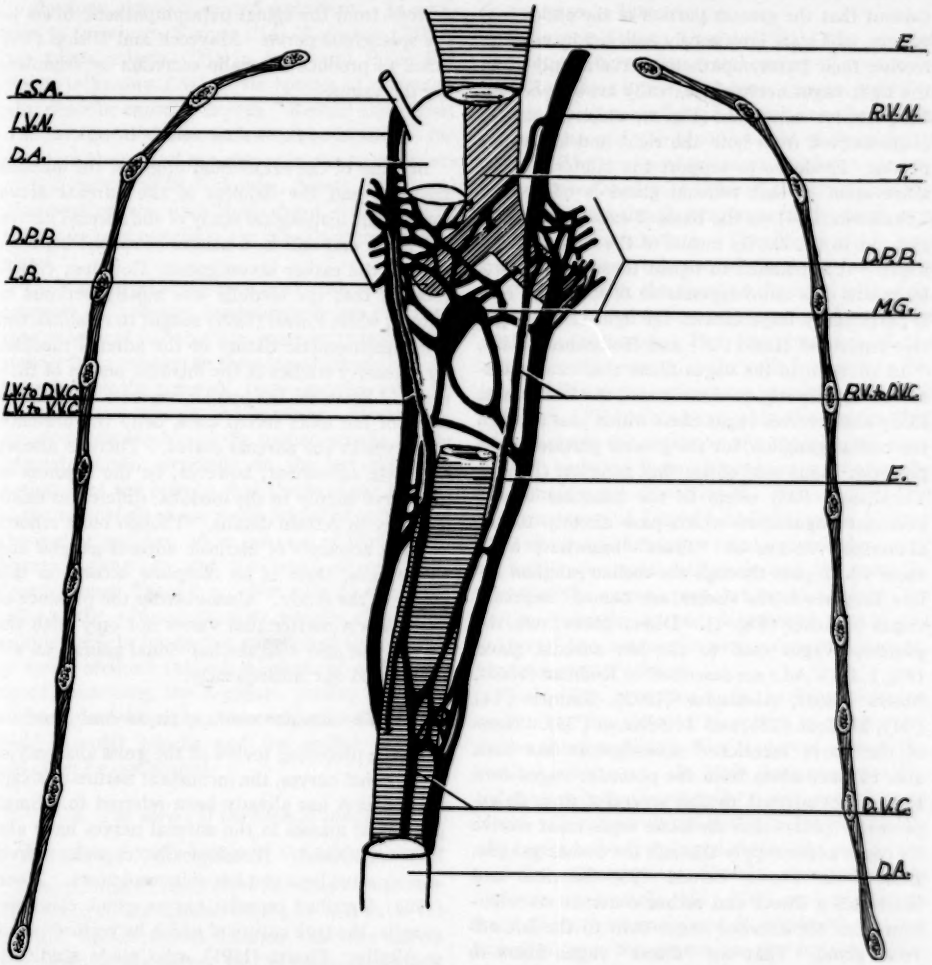

FIG. 2. THE DORSAL VAGUS CORD OF A NEW BORN INFANT DISPLAYED IN A DORSAL DISSECTION

The dorsal thoracic wall has been removed, exposing the dorsal aspects of the thoracic viscera. The dorsal vagus cord is formed by the union of rami derived from the left and right vagus nerves. D.A., descending aorta (partly resected); D.P.P., dorsal pulmonary plexus; D.V.C., dorsal vagus cord; E., esophagus (partly resected); L.B., left bronchus; L.S.A., left subclavian artery; L.V. to D.V.C., left vagus ramus to dorsal vagus cord; L.V.N., left vagus nerve; L.V. to V.V.C., left vagus ramus to ventral vagus cord; M.G., mediastinal ganglion; R.V. to D.V.C., right vagus rami to dorsal vagus cord; R.V.N., right vagus nerve; T., trachea.

(Modified slightly from H A. Teitelbaum and E. Uhlenhuth. *Anat. Rec.*, v. 52, p. 24, 1932. By courtesy of the Wistar Institute of Anatomy and Biology.)

there are a number which do offer accurate descriptions: Jackson ('25), Hovelacque ('27), Robinson ('31), Greving ('31), and others. Of historical anastomoses in his illustrations; while Willis (1720) and Walter (1783) offer illustrations which demonstrate the distribution of the vagi correctly.

Haller (1766) also describes the intervagus anastomoses about the esophagus.

With the above as a basis, it becomes quite evident that the greater portion of the abdominal viscera, which are erroneously believed by some to receive their parasympathetic nerve supply from the right vagus nerve alone, really are supplied by the posterior vagus cord (Fig. 1), which consists of fibers derived from both the right and left vagus nerves. Evidence to support the bilateral vagus innervation of each adrenal gland is offered by Teitelbaum ('34) on the basis of experiments carried out in the cat by means of the Marchi technique. It is planned to repeat these experiments by means of a more dependable technique. This is particularly important in the light of the negative reports of Hoshi ('27) and Hollinshead ('36).

In addition to the vagus fibers that can be dissected out directly to the adrenal, the latter most likely also receives vagus fibers which pass through the coeliac ganglion, for the greater portion of the posterior vagus cord enters that ganglion (Fig. 1). Teitelbaum ('33) refers to the branches of the posterior vagus cord which pass directly to the abdominal viscera as "direct" branches; while those which pass through the coeliac ganglion before they reach the viscera are named "indirect" vagus branches (Fig. 1). Direct fibers from the posterior vagus cord to the left adrenal gland (Fig. 1, Di.V.Ad.) are described by Kollman (1860), Moers (1864), Alexander (1892), Renner ('14) ('31), McCrea ('25), and Teitelbaum ('33). None of the above mentioned investigators has been able to trace fibers from the posterior vagus cord to the right adrenal, though several of them do express the opinion that the latter organ must receive its vagus nerve supply through the coeliac ganglia. Besides the above, Uchida ('28) describes and illustrates a direct and rather constant contribution from the anterior vagus cord to the left adrenal gland. That the "direct" vagus fibers to the adrenal are not found constantly is illustrated by Teitelbaum ('33).

In contrast to the anatomical findings described above, Hoshi ('27) and Hollinshead ('36) could not demonstrate any changes in the nerve fibers present in the adrenal gland after having sectioned the vagus. Splanchnic section, however, resulted in the degeneration and disappearance of the nerves in the adrenal medulla. In agreement with the above, Kure, Wada and Okinaka ('31c) report that section of both vagi below the diaphragm failed to cause degeneration of the fine medullated fibers passing to the adrenals. They claim that the vagus has no relation to the adrenal gland, for the parasympathetic nerve supply to the latter is derived from the spinal parasympathetic fibers in the splanchnic nerve. Maycock and Hislop ('39) failed to produce adrenalin secretion by stimulating the vagus.

II. HISTOLOGY OF THE ADRENAL NERVES

Because of the ectodermal origin of the adrenal medulla, and the richness of the adrenal nerve supply, the histological study of the adrenal nerves has been, and still is, a matter of special interest. Among the earlier investigators, Gottshau (1882) thought that the medulla was mostly nervous in nature; while Fusari (1891) sought to establish the sympathicogenetic nature of the adrenal medulla by extensive studies of the intrinsic nerves of that organ. Some of the earlier reports, as well as some of the more recent ones, deny the presence of nerves in the adrenal cortex. There is almost complete agreement, however, on the richness of the nerve supply to the medulla, differences existing only in certain details. Though most reports contain accounts of intrinsic adrenal ganglia and nerve cells, there is no complete accord on this phase of the study. Undoubtedly the presence of ganglia is a matter that varies not only with the species but also with the individual animal, as will be pointed out subsequently.

A. The capsular nerves of the adrenal gland

In the preceding review of the gross anatomy of the adrenal nerves, the inconstant nature of a capsular plexus has already been referred to. Small ganglionic masses in the adrenal nerves have also been mentioned. Histologically, capsular nerves are reported by a number of investigators. Moers (1864) described capsular nerves which contained ganglia, the true nature of which he verified microscopically. Fusari (1891), who made studies in man, mice, rats, rabbits, hogs, cats and goats, observed a capsular plexus which also contained small ganglia. According to him, ganglia are found in, as well as immediately beneath, the capsule. Not all of the nerves that enter the capsule are distributed to the adrenal gland, however, for some of them leave the capsule, and others penetrate the cortex only to alter their course and pass out again. Kolmer ('18) and Hollinshead ('36) have confirmed this observation. Most of the capsular nerves are, however, ultimately distributed to the adrenal parenchyma. Dogiel (1894) also described cap-

sular plexuses in several different species of animals, and he observed that these plexuses were intimately associated with the nerves distributed to the zona glomerulosa and reticularis. In addition to the above, Renner ('14), Kolossow ('30) in the turtle, Alpert ('31) in man, and Pines and Narowtschatowa ('31) in six species of mammals also describe capsular nerves. Renner and Alpert confirm the intimate relationship between the capsular plexus and the nerves in the outer layers of the cortex; while Kolossow, Alpert, Pines and Narowtschatowa, and Hollinshead ('36) confirm the presence of ganglia in the capsule of the adrenal gland.

In histological studies of adult cat and kitten adrenals, Teitelbaum (unpublished) has observed that ganglia of variable size, some quite large, constantly lie in relation to the adrenal gland (Fig. 3). Less frequently some of these ganglia may be buried in the capsule of this gland. Because of the close relationship of the coeliac ganglia to the adrenal glands, especially on the left side, the author is of the opinion that the capsular ganglia of the adrenal gland are really displaced portions of the coeliac ganglion, as in the case of Hirt's "epiphrenic" ganglion, and the renal, or oft-called "aortico-renal," ganglion. Not only do the nerve cells in the adrenal capsular ganglia closely resemble those in the coeliac ganglion of the cat, but in serial sections through a block of abdominal tissue containing the adrenals, coeliac ganglion, and adjacent structure, the continuity of the adrenal capsular ganglia and the coeliac ganglion can often be established.

B. The nerves of the adrenal cortex

1. The parenchymal nerves of the adrenal cortex

Though Nagel (1836) observed that nerves were distributed to the adrenal cortex as well as to the medulla, Moers (1864) claimed that the nerves pass through the cortex to the medulla without being distributed to the cells of the former at all. According to Fusari (1891), Nagel was the only one of the earlier investigators to describe nerves in the adrenal cortex. Fusari also observed many nerves in the cortex. Each capillary, according to him, is accompanied by at least one fine nerve fiber. There are also other nerves which are independent of the blood vessels. The nerve fibers of the adrenal cortex arise either from the capsule or from the medulla; or more rarely from the nerve bundles which pass through the cortex. Concerning the ultimate terminations of the cortical nerves, Fusari states that the cortical cells do not have any intimate relationship with the nerve fibers as is the case in the medulla.

Following Fusari, Dogiel (1894), who studied the adrenal nerves in several species of mammals, classified these nerves into three groups; capsular, cortical, and medullary. Dogiel describes nerve plexuses around the blood vessels of the adrenal gland. The nerves of the capsular plexus are intimately associated with those of the zona glomerulosa, and from the glomerular zone the fibers pass to the zona fasciculata. The fibers which pass between the cell columns of the zona fasciculata anastomose with the fibers of the zona reticularis, which has the richest nerve supply of the three zones in the cortex. The finer branches of the cortical nerves surround the cells in groups. No intercellular nerve endings are present.

Elliott ('13) pointed out that the nerves that pass through the cortex to the medulla are myelinated; and that these nerves degenerate after the splanchnic nerve is sectioned. Renner ('14, '31) confirms most of Dogiel's findings; while Kolmer ('18) observed that nerve trunks pierce the cortex to supply the zona reticularis and the medulla. Some of the nerves pass out again through the cortex, however, to end somewhere else in the sphere of the autonomic nervous system, according to the latter author.

Hoshi ('27), reverting to the earlier conception concerning the absence of nerves in the cortex, denies the fine distribution of nerves among the cortical cell groups. In birds the nerves are distributed only to the medullary cells, according to Hoshi. In mammals the nerves pierce the capsule and cortex to be distributed among the cells in the medulla. Contrary to Hoshi's observations in birds and mammals, Hirt ('30) reports that in frogs (*Rana temporaria* and *R. esculenta*) the fine branches from the plexus on the surface of the adrenal penetrate into the latter, and spread out among the individual cells. Though Hirt could find no nerve endings, he did note that there was no difference in the relationship of the nerves to the medullary and cortical cells.

In the turtle (*Emys europaea*) Kolossow ('30) observed that the cortical (interrenal) tissue of the adrenal is not as richly supplied by nerves as is the medullary tissue. The cortical fibers are thicker than those of the chromaffine tissue, and they surround cell groups rather than individual

cells. Kolossow is of the opinion that the failure to follow the cortical fibers into the cell groups, and see their ultimate termination among the cells, is due to technical difficulties which arise from the presence of the cortical lipoid.

On the basis of the findings already mentioned one might readily conclude that the absence of nerve endings in relation to the individual cortical cells is an established fact, but more recently Alpert ('31), in his detailed study of the human adrenal, came to conclusions diametrically opposed to that mentioned above. According to Alpert, the nerves of the cortex are non-myelinated, and they enter either along with the blood vessels or alone. The zona glomerulosa receives its nerve supply from the capsular nerves, and not only the glomerular cell groups, but also the individual cells of these groups are surrounded by nervous networks. In addition, Alpert describes intracellular nerve terminations. The zona fasciculata is supplied by fibers derived both from the capsule as well as from the zona glomerulosa. They pass between the cell columns to which they give off branches. These branches form plexuses around the cell columns, and give rise to fine intercellular as well as intracellular nerve endings. The zona reticularis nerve plexuses which are derived from the fascicular and capsular nerves are richer than those located in the more superficial cortical layers, and they also give rise to pericellular networks and intracellular nerve endings.

Alpert stands more or less alone in his findings concerning the finer details of the nerve endings in the cortex, for even Pines and Narowtschatowa ('31), who studied the adrenal nerve supply in the ox, rabbit, cat, dog, mouse and rat, using the Cajal, Weigert and Nissle techniques, conclude that the cortex is sparsely innervated in comparison to the medulla, and that the nerves end in relation to cell groups rather than individual cells. More recently Hollinshead ('36) in the cat and Swinyard ('37) in the cat and in man, contrary to Alpert, failed to find any definite evidence of cortical innervation.

The extreme differences reported above might be explained either on the basis of the different species of animals studied, or on the basis of technical difficulties involved in staining the nerves in the adrenal cortex, as mentioned by Kolossow. These difficulties have been duly impressed upon the mind of the author in his efforts to stain the adrenal nerves by means of Bielchowsky's pyridine-silver technique. In the case of the cortex, one must not only contend with connective tissue affinity for the silver, but also with the avidity of the cortical cells themselves for that metal.

2. The vaso-motor nerves of the adrenal cortex

Detailed studies of the terminations of the adrenal nerves in relation to the blood vessels of that gland, as have been made in the thyroid gland, for instance, by Anderson (1894), Briau (1897–98), Rhinehart ('12), Popow ('28), and Nonidez ('31, '32), have not been made—at least not as far as the knowledge of the author is concerned. Fusari (1891) observed that each capillary is accompanied by at least one fine nerve fiber; while Dogiel (1894) states that the nerves form plexuses around the larger blood vessels and capillaries, thus disagreeing somewhat with Fusari, who does not report any plexuses. Alpert ('31) remarks that the nerves may enter the cortex either in company with blood vessels or alone, and that nerves in the zona fasciculata pass between the cell columns along with the blood vessels. In the medulla Alpert found that nerve cells are occasionally located in the walls of the blood vessels. Pine and Narowtschatowa ('31) are no more enlightening on this subject than are their predecessors, for they merely mention the fact that the nerves usually follow the blood vessels. The more recent work of Hollinshead ('36) in the cat reveals that small groups of lone fibers accompany blood vessels into the cortex and lose themselves on the walls of these vessels. In the medulla some fibers run in contact with blood vessels. Nerve fibers can be seen in the media of the vessels, and are apparently concerned with the innervation of the musculature.

Though no detailed histological studies of the terminations of the vaso-motor nerves in the adrenal gland are available, that such nerves actually exist has been well substantiated by many physiological experiments: Biedl (1897), Dreyer (1898–99), Hallion ('21), Schklawera and Kusnetzow ('23) and Kure, Wada and Okinaka ('31c).

3. The intrinsic ganglia of the adrenal cortex

Though there is rather unanimous agreement concerning the existence of capsular ganglia, no such harmony exists with regard to ganglia in the adrenal gland itself. Dogiel (1894) states that nerve cells are present either singly, in small groups, or in ganglia. They are usually located in the nerve trunks, mostly in the medulla, and only rarely in the cortex. That the presence of ganglia

in the adrenal gland varies with the different species, and most likely even with the individuals of any one species, is made quite evident by Dogiel, for he states that nerve cells are most commonly found in the guinea pig, while they are less numerous in the dog and cat, and rare in the rat. Though having studied literally hundreds of sections through cat adrenals, the author has never observed any nerve cells in either the cortex or medulla of that gland. Renner ('14, '31) could find no ganglia in the adrenal cortex; while Hoshi ('27), who seldom observed nerve cells in the cat and guinea pig, failed to find them in the rabbit, either in the cortex or medulla. Though Alpert ('31) and Hollinshead ('36) mention no cortical ganglia, Pines and Narowtschatowa ('31) describe nerve cells in all parts of the adrenal gland, including the cortex. The nerve cells in the adrenal vary considerably in number in different animals according to these authors. They may be multi- or bipolar, and are characteristically sympathetic in nature.

The inconstancy of nerve cells in the adrenal gland is most likely characteristic of the other endocrine glands also. Evidence that such is the case for the thyroid is presented in a recent review on the innervation of that gland by Teitelbaum ('34a).

C. The nerves of the adrenal medulla

1. The parenchymal nerves of the adrenal medulla

In contrast with the negative findings of Hoshi ('27), Hollinshead ('36), and Swinyard ('37) concerning the existence of nerves in the adrenal cortex, there never has been any doubt as to the presence of nerves in the adrenal medulla. As a matter of fact some of the earlier histologists were actually of the opinion that the cells of the adrenal medulla were neural in nature. Moers (1864) refers to the fact that Kolliker believed that the adrenal medulla was made of nerve cells. Moers himself was skeptical of this opinion, but nevertheless he states that if the medullary cells are nervous in nature they are associated with the nerve trunks in the adrenal and not with the adrenal gland itself. Concerning the distribution of the nerves in the medulla, Moers states that after piercing the cortex they branch considerably among the medullary cells. Nagel (1836), who preceded Moers, also observed the branching of the nerves distributed to the adrenal medulla. Gottschau (1882) believed that the medulla was mostly nervous in nature, but he nevertheless denied that it could really be considered as part of the nervous system. Gottschau came to the conclusion that the medulla fundamentally resembles the cortex; thus, knowingly or unknowingly, he classified it as a glandular organ.

Though these earlier investigators reported the presence of nerves in the adrenal medulla, Fusari (1891) was among the first to give accurate detailed descriptions of the distribution of these nerves. The anastomoses and points of crossing among the small nerve bundles are so numerous, according to Fusari, that the entire medulla contains an extensive plexus of nerve fibers in good preparations. Each group of medullary cells was found to be contained in a reticulum of nerve fibers, the nodes of which were applied to the cells, for the fibers lying in relation to the medullary cells were provided with discoidal nodules or small polygonal placques.

According to Dogiel (1894), the medulla receives those nerves which are not distributed to the capsule, but which pierce directly into the adrenal parenchyma. The medullary nerves give rise to fine branches which build intricate plexuses among the cells. Varicose fibers penetrate between the cells where they anastomose to form plexuses. Renner ('14, '31) confirms the descriptions presented above, but Kolmer ('18), who found the nerves in the guinea pig medulla to be almost exclusively non-myelinated, could not find any fibers which ended as secretory nerves usually do in glands. Kolmer believed that many of the nerves in the adrenal medulla had their origin in that organ, and he therefore suggested that the nerves arising in the adrenal medulla had different chemical and morphological affinities from those which entered from without. As has been previously mentioned, Kolmer conjectured that the secretory product of the adrenal medulla is in some way released through the adrenal nerves. In the human adrenal Kolmer observed that some myelinated nerves pass to the medulla where they end in lamellated enlargements of complicated pattern. These enlargements have connective tissue sheaths.

In the frog, Hirt ('30) observed that the nerves pass from the adrenal capsule into the parenchyma of that gland, and spread out to surround the individual cells without giving rise to any nerve endings. In the turtle Kolossow ('30) describes

the fine nerves of the chromaffine tissue as penetrating among the strands of medullary cells to form intricate plexuses. The fibers ultimately terminate in relation to the individual cells. One fiber may come in contact with several cells. Contrary to Hirt's observations in the frog, Kolossow reports that the nerve fibers in the turtle medulla bear enlargements which are approximated to the cells. A fine network is discernable in these enlargements. Kolossow is of the opinion that the turtle medulla is not as richly supplied with nerves as is the mammalian adrenal medulla.

Alpert ('31) does not agree with the contention of Dogiel that the nerves to the medulla do not arise from the capsular nerves, but rather from those which pierce the adrenal parenchyma directly. Alpert classifies the nerves to the human adrenal medulla into three groups: (1) Myelinated nerves which arise from the capsule and pass to the medulla where they form synapses with the nerve cells present. These nerves lose their myelin in the medulla. (2) Non-myelinated fibers that are distributed to the region between the zona reticularis and medulla. These pass at right angles to the fibers of group (1), and give rise to branches that pass into the medulla. (3) Nerves in the walls of the large blood vessels that enter the medulla. These are fine and non-myelinated. Concerning the finer ramifications of the medullary nerves, Alpert states that they anastomose little, are finer than the cortical fibers, a condition observed in the turtle by Kolossow, and they enmesh the cells both in groups as well as individually, giving rise to intracellular terminations that end near the nuclei of the chromaffine cells.

Pines and Narowtschatowa ('31) do not agree with Alpert's finer details, for they describe intricate plexuses which give rise to fibers bearing varicosities and intercellular endings. Though no intracellular endings were observed, these authors describe fibrillar end-knobs which end in the connective tissue, and which they consider as afferent in nature. Popow ('28) has described similar endings in the thyroid and he interprets them as afferent also. It must be kept in mind, that while Alpert studied the human adrenal, Pines and Narowtschatowa studied the adrenals of several mammals, not including that of man, however.

More recently Hollinshead ('36) described a delicate plexus in the cat medulla. This surrounded the cell groups, and gave rise to fine fibrils that passed between the cells. The nerve endings consisted of end bulbs and ring-like terminations. The larger bulbs sometimes resembled cells. No intracellular endings were found. While the smaller fibers were found to cross frequently there was no evidence of anastomosis. Swinyard ('37) confirmed the findings of Hollinshead.

As has already been mentioned, on the basis of the findings of Elliott ('13), Hoshi ('27), Hollinshead ('36), and Swinyard ('37), a good portion of the nerves in the adrenal medulla are preganglionic and splanchnic in origin, and they are supposed to terminate in relation to the cells of the adrenal medulla without the intermediation of an intercalated neuron.

2. The vaso-motor nerves of the adrenal medulla

As in the case of the cortex, few of the investigators mentioned above have paid much attention to the relation of the nerves in the adrenal medulla to the blood vessels of that organ. Alpert ('31) describes ganglion cells as lying in the walls of blood vessels occasionally. According to Pines and Narowtschatowa ('31), nerves follow the blood vessels and branch simultaneously with the latter. Even the smaller vessels are accompanied by nerves. The plexuses, which form about the vessels, give rise to nerve endings which penetrate to the adventitia and media and serve vaso-motor functions. These findings are confirmed by Hollinshead ('36), who was also able to find nerve fibers in the media of the vessels.

3. The intrinsic ganglia of the adrenal medulla

Moers (1864) mentions the presence of ganglia in the adrenal gland. Gottschau (1862), who studied the adrenals of man, cattle, and sheep, observed that there was a preponderance of nerves and nerve cells in the inferior pole of the adrenal. Gottschau was of the opinion that the adrenal medulla was mostly nervous in nature. This conception is most likely the foundation of the theory of neural transmission of adrenalin invoked impulses, as suggested by Jacobj (1892), Elliott ('13), Kolmer ('18), Rindt and Kahn ('29), and Crile ('31). That the chromaffine cells do have a peculiar relation to the nerves in the medulla is evident from the work of Elliott ('13) and Hoshi ('27). Contrary to the condition existing in other organs, the chromaffine cells are innervated by preganglionic rather than postganglionic neurones. This would indicate that these cells are probably modified post-ganglionic neurones.

The finer details of the nerve cells found in the adrenal have been described by Fusari (1891).

According to him, both the large nerve bundles as well as the smaller branches contain nerve cells. The number of these cells varies in different species of animals, being frequent in the rabbit and less numerous in the goat and mouse. The cells measure from 8 to 30 microns in diameter, and are fusiform or spherical in shape. Both types of cells have two prolongations as a rule. In some cases there may be only one process, probably due to the failure of the smaller process to take up the stain; for when two prolongations are present, one is large, and one small. The larger prolongation is continuous with the fibers of the nerve proper, while the smaller one penetrates into the medullary parenchyma in true postganglionic fashion.

Nerve cells may also be found along the sides of nerve bundles, especially in rabbits. These cells are usually spherical and they possess two prolongations, the larger of which joins the bundle while the smaller is distributed to the parenchyma. Other polygonal nerve cells are present and are provided with branched prolongations. These cells are located along the smaller nerve bundles and isolated fibers which are found among the groups of medullary cells.

Dogiel (1894) does not entirely agree with Fusari's description of the nerve cells in the adrenal medulla. He claims that they are most numerous in the guinea pig, less numerous in the dog and cat, and seldom present in the rat. Dogiel describes small and large multipolar cells. The processes of the small cells form plexuses around the larger ones. One of the processes could be followed to the cells of the medulla, as described by Fusari. The significance of the pericellular network in relation to the larger nerve cells is really difficult to surmise. Dogiel claims that bipolar nerve cells may also be present near the multipolar cells.

Though not agreeing with all of the findings of either Fusari (1891) or Dogiel (1894), Renner ('14, '31) confirms some of the observations of both. According to Renner, the medullary nerve cells lie either individually among the chromaffine cells or in groups of 2 to 30. They are of the sympathetic type. The isolated cells have no capsules, but the grouped cells are definitely encapsulated. The processes of the isolated cells end in direct relation to the medullary cells, contrary to Dogiel's observations. The small bipolar cells of Dogiel were found by Renner in several animals, but not in man.

Opposed to Dogiel's (1894) observations in the guinea pig is the failure of Kolmer ('18) to find any nerve cells in the adrenal medulla of that animal. Though Kolmer believes that nerve cells can be found in some animal forms, he contends that the presence of an abundance of nerve cells in the adrenal medulla, as maintained by the earlier investigators, must be viewed with skepticism. Nerve cells in the adrenal medulla are the exception rather than the rule, according to Kolmer, and his contention is supported by Hoshi ('27) who could not find any nerve cells in either the cortex or medulla of the rabbit. The author's

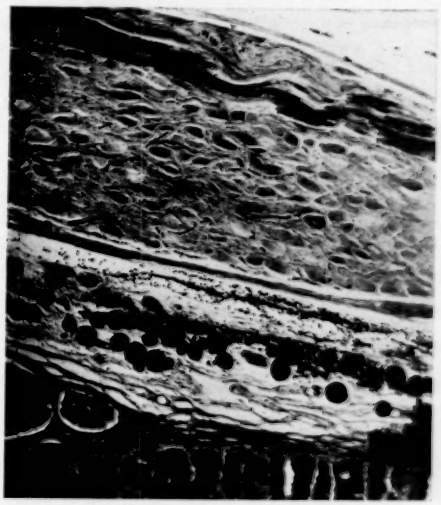

FIG. 3. GANGLION IN CAPSULE OF ADRENAL GLAND OF THE CAT

The cells of the zona glomerulosa of the cortex are evident with their lipoids stained black. (Marchi technique.)

observations in the cat also confirm Kolmer's views. Hollinshead ('36) could find only few nerve cells in the cat medulla, and these inconsistently.

Alpert ('31) in man, and Pines and Narowtschatowa ('31) in several species of mammals, do not agree with Kolmer. Alpert describes ganglion cells as being present in all parts of the medulla, even in the walls of the blood vessels. Nerve fibers enter the nerve cells and emerge through the processes to terminate among the medullary cells. According to Pines and Narowtschatowa, the nerve cells which are present in all parts of the adrenal, as well as in the nerve bundles themselves, are characteristically sympathetic. They vary

considerably in number, may be isolated or grouped, and either multi- or bipolar.

The significance of the data on the presence or absence of nerve cells in the adrenal medulla is not a matter of mere morphological interest if the findings of Elliott ('13), Hoshi ('27), Hollinshead ('36), and Swinyard ('37) are recalled. If the adrenal medulla does contain a rich supply of nerve cells, then it is possible that the splanchnic nerve preganglionic fibers to the adrenal do not end in direct relation to the chromaffine cells but rather in relation to the nerve cells in the medulla. However, if those are correct who contend that the presence of nerve cells in the adrenal medulla is an exception rather than the rule, then the preganglionic splanchnic fibers do end in direct relation to the chromaffine cells, as maintained by Elliott and Hoshi.

III. SUMMARY

The apparently excessive nerve supply to the adrenal gland is related to its ectodermal organ and to its proximity to the coeliac plexus. The adrenal gland is innervated through the adrenal plexus, which receives its fibers from the splanchnic nerve, sympathetic trunk, coeliac ganglion, vagus nerve, and sometimes the phrenic nerve.

The sympathetic nerves to the adrenal arise in the lower thoracic spinal segments and traverse the splanchnic nerves and sympathetic trunks. Some of these fibers pass directly to the adrenal from the splanchnic nerve, without first passing through the coeliac plexus. The parasympathetic nerves to the adrenal are usually derived from the dorsal vagus cord (Figs. 1 and 2) and sometimes from the anterior vagus cord also. According to Kure, spinal parasympathetic fibers pass to the adrenal through the splanchnic nerve. The vagus fibers may either pass directly to the adrenal or they may first traverse the coeliac ganglion (Fig. 1). Some authors deny the distribution of vagus fibers to the adrenal gland. Fibers to the adrenal from the phrenic nerve, as well as from an epiphrenic ganglion, have been described.

Histologically, a capsular plexus containing ganglia (Fig. 3) has been described. While some investigators have found nerves in the adrenal cortex, others deny their presence. There is complete agreement on the extensive innervation of the cells of the adrenal medulla. The presence of nerve cells is not a consistent feature. There is only a paucity of anatomical data on the innervation of the adrenal vessels.

Owing to the present war conditions the author has been unable to see his paper in galley proof.

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THE INTEGRATION OF VEGETATION

By W. F. GERICKE

INTRODUCTION

CONFORMATION expresses the adaptation of the plant to its environment. The multiplicity of species and varieties expresses the adaptation of vegetation as a whole to the diversities of soil and of climate. Integration of vegetation into a unity concept of adaptation, of form, of mineral absorption, of photosynthesis, and of crop-production per unit area exposure to sunlight is based on features that express the dependency of various plant parts on each other, but particularly the organs that absorb mineral nutrients and those that produce organic food for the roots. Conformation of plants changes with their advance in age. The features whereby species are arranged into an orderly assemblage of gradations, of continuities, and of harmonies to a cosmic surrounding express this dependency progressively with age and with changes in environment. The features which express the dependency of photosynthesis on the mineral absorption, and vice-versa, the mineral absorption on photosynthesis, are the primary elements for integration. They follow a common pattern of change in all plants, with climate as the chief cause of plant distribution. With the roots of plants obscured in the soil this pattern of change with climate could not be observed with sufficient clarity to integrate vegetation, but in hydroponics, with the growing roots visible so that they could be seen and studied, the results obtained in the last few years, from hydroponicums located in different climates, have now yielded the needed information for the integration of vegetation.

The conformation of a plant expresses the differences in the rates of growth of its parts. As plant distribution and culture are oriented by what climate permits, the rates of growth of the parts at different temperatures and light intensities hold the key to integration. Temperature and light are the primary cosmic forces influencing certain chemical reactions fundamental in the origin of biologic forms and in their adaptation to various regions. Form reflects the character of a plant's mineral nutrition and photosynthesis, and thereby the yielding capacity of agricultural crops per unit area of surface exposed to sunlight. The integration of vegetation is based on the effects the primary cosmic forces have on the features which express the dependency of photosynthesis on mineral nutrition, and mineral nutrition on photosynthesis. Placing species according to the amounts of mineral nutrients absorbed per plant per unit weight of plant and per unit area, also according to the amounts of sugar, starch, protein, and other products produced, the orders reveal progressive gradations in root and leaf characters which show both their interdependent and complementary relations.

Conformation of plants is expressed by the ratios of the parts to each other

Conformation is expressed by using plant parts as the standard of comparison, expressing the measurements as ratios instead of as single dimensions. The dependency of photosynthesis on the mineral nutrition, and vice-versa, is implied by the ratio of root characters to that of tops. Species can be segregated into an array of categories by ratios such as weight of roots to tops—root diameter to leaf width—root diameter to total leaf area—root diameter to stem diameter—root spread to top spread—length of growth period of roots to total growth period of plants—and others. Closely allied species of similar leaf type such as wheat, oats, barley, rye, rice, corn, and sugar cane can be arranged in order of yielding capacities, amounts of mineral nutrients absorbed, and other characters, by one feature only, such as the ratio of root diameter to leaf width. Several features are required to place the species of dissimilar types in the order of their yielding capacities and mineral absorption. A low weight ratio of roots to tops indicates low mineral absorption as the intake of nutrients is conditioned by root growth. However, mere root growth among vegetation at large is, in itself, not a measure of the amount of mineral nutrients absorbed. Some species of high root-top ratio have low mineral absorption. No rapidly growing species of low root-top ratio such as water-

melon, and other vine crops, has high mineral requirement or absorption, but slow growing ones such as desert species might have. Vine crops usually require very rich soil to compensate for the low absorptive capacities of the roots.

Temperature and light affect the ratios of root to top growth

It is common knowledge that roots cannot stand as high temperatures as the leaves, hence the lowest root-top weight ratio for any species prevails in the hottest climate in which it can be grown, while on the other hand the highest root-top weight ratio is attained in cooler climates for which the species is adapted. The highest mineral absorption per plant corresponding to the largest root growth is in the cooler climate, but due to restriction of growth at highest temperature, the amount expressed as per cent might not show this difference, and in some plants might be higher for certain elements. The highest root-top ratio does not always prevail at the lowest growth temperature for all plants, for the roots of some species can not stand as cold temperature as the leaves.

The effect of increasing light intensities on root growth is different from that of temperature. Highest root-top ratio prevails where light is adequate for maximum photosynthesis, which for all high energy crops is full exposure to the summer sunshine. Lowest root-top ratio prevails where light is inadequate for maximum photosynthesis, but still adequate for foliar growth without leaves losing any color when the plants are grown at normal summer temperatures. Under such inadequate light conditions, leaves attain very large size but lack or are low in sugar or starch. The largest quantity of sugar in sugar beets, the largest amount of starch in wheat, the sweetest tomatoes, and the sweetest fruits of vines or trees are never produced by plants which have the largest leaves the species can produce. The largest yield of starch, sugar, or protein per unit area is obtained under light conditions which cause a moderate restriction from the maximum leaf size which the species is genetically capable of producing. This is in conformity with the laws governing plant conformation. It is a factor to be considered in the integration of vegetation into a unity concept of adaptation to its environment.

Species of the same general leaf-type and root growth can be placed in order of the yielding capacities for starch or sugar per unit area by the ratio of root diameter to leaf width. The order for the largest yield per acre of the seven important members of the grass family is sugar cane, corn, rice, barley, wheat, oats, rye. It is significant in the study of adaptation, but must be passed here without comment, that the largest yields of each of these crops reported for the northern hemisphere were obtained in the northern half of the latitudinal zone in which the crop is grown. The order of the production data of the seven crops stated above is in agreement with the placement of the species by the diameter of the thickened roots, which convey organic food to the younger, thinner, and more remote mineral absorbing roots. It is also in agreement with the placement of the species for leaf surface per unit area of earth surface exposed to sunshine. However, these crops have different lengths of growth periods, but arranging the production data for an equal length of time the order is corn, sugar cane, rice, barley, wheat, oats, rye, and is in general agreement with placement by leaf width except for oats, which should stand before wheat. There is, however, overlapping of varieties, particularly rice, barley, wheat, and oats, when placement is by leaf width only, but considering only those varieties which are best suited for the general area in which the crop is grown extensively, leaf width indicates the relative productive capacity of each species. Varietal characteristics that cause overlapping when placement is by one feature only, however, gave the key to integrate other groups of vegetation, for variation in one character has correspondence in another which can be traced in the varieties of the same species.

Placement of principal crops of grass family for various characters by root to top ratios

By the law of conformation in plants, one dimension indicates others. Leaf width in cereals gives an approximation of the total leaf area of the species. Similarly, the thickness of the roots conveying organic food in the upland cereals gives a measure of the spread of their mineral absorbing roots. The largest amount of nitrogen absorbed from an acre of land by the crop of widest geographic distribution was from the largest yield of wheat which was approximately 7500 pounds of grain. The root-leaf features of this crop give the basis for comparison of absorption of this element by other species. As the diameter of the roots conveying organic food to the mineral absorbing

roots increases in barley, rice, corn, and sugar cane the per cent nitrogen in the plant becomes smaller but the total amount absorbed may be the same, larger, or smaller, depending on size of the plant. The corn plant absorbs much more nitrogen than the wheat plant because it has more root area of the same diameter and character as wheat. Rice and barley which do not exceed wheat in size have less nitrogen per plant, but varieties of both, having large tillering capacities, do absorb more than those wheat varieties which tiller sparsely. As the diameter of the roots conveying organic food decreases in rye and in the species of all other groups of vegetation, the per cent nitrogen in the plant, or the total quantity absorbed per unit area of land, decreases. Rye has the narrowest leaf, and the lowest leaf area per unit height of plant, of the common cereals extensively grown. Rye grain varies least in nitrogen of the high protein cereals. Emmer, a wheat, has narrow leaves and likewise varies little in protein compared to the broader-leafed bread wheats. Oats varies considerably in leaf size and root diameter, which is reflected by variation in the nitrogen content of the grain. Wheat has the greatest range of variation in per cent and amount of protein in the grain of all cereals as the protein may constitute from 6 to 28 per cent of the weight of the seed. Species of large roots such as corn vary less in nitrogen than those having smaller root diameter, but very fine roots do not have high absorptive capacity for nitrogen and hence variation is small in such cases.

Effect of root and leaf characters on the variation of protein in the cereals

Every species and variety has a minimum or irreducible per cent of nitrogen and of each of the other nutrients below which the plant or its products can not exist. Variation in the per cent protein of any species or variety can be expressed as the quantity of nitrogen absorbed above the plant's minimum requirements. Variation in per cent protein is due to those quotas of nitrogen absorbed during the latter growth stages of the plants as that which is absorbed early functions for maximum vegetative enlargement, which is the complement of the minimum. Withholding nitrogen from the culture media during the latter growth stage of wheat results in large yields of low protein, well filled, high starch content grain. Maintaining ample supply throughout the entire growth period results in high protein grain with lower starch content. Similar treatment of rye or rice has little or no effect in changing the nitrogen content of the grain. The narrow-leaved rye and its smaller leaf area per unit height of plant restricts photosynthesis compared to that of wider-leaved species and consequently the amount of organic food for the absorbing roots. The absence of thickened roots which convey organic food precludes large spread of the finer roots and lessens the plant's absorbing capacity. Significant differences in thickness of roots usually do not show in seedlings a few weeks old, but show when the plants are in full vegetative vigor and greatest photosynthesizing capacity. In laboratory studies where plants were grown under glass in small containers of nutrient solution these differences could not show up because of limited photosynthesis. Rice has the thickest roots of all the small grain cereals but has very limited spread of fine roots of the diameter of those of wheat when the plants obtain full size. Consequently, rice generally is the highest in per cent starch and lowest in per cent protein of the cereals. In certain varieties where this may not hold, the explanation lies in the smaller diameters of the roots and narrower leaves. By proper grouping of plants, thickness of roots can be used as a measure of the quantity and quality of mineral absorption of different species and varieties. Rice grown in water submerged fields or paddies has the lowest root-top ratio and the lowest mineral absorption of the cereal crops. Corn has the greatest spread of fine roots of the diameter of those of wheat which bear from the thickened roots. It exceeds all cereals and sugar cane in photosynthetic power, mineral absorption, and protein production per plant. Sugar cane has the largest spread of thickened roots of this group of plants. They drive deeply into cooler soil below, overcoming the effect hot climate has on the root-top ratio of finer rooted plants.

When species of similar leaf types having moderate rates of growth are arranged in the order of increase in leaf size, their starch and sugar production per unit area of earth's surface increases, and conversely, when they are arranged in descending order for leaf size, their protein content increases. These products are in part complementary, and the conditions favorable to a plant for high production of protein is unfavorable to its highest production of starch or sugar, and vice-versa. Plants high in starch, sugar, or protein

have relatively high root-top ratio and mineral absorption. Plants having low root-top ratio have correspondingly low mineral absorption and low production of starch, sugar, or protein per unit area.

The ratios of the diameters of the thickened roots to the widths of the leaves in the high energy plants of the grass family are narrow and essentially alike in all species, as the wider-leaved plants have correspondingly thicker roots. Similarly, other high energy plants, not members of the grass family, such as potatoes, likewise show the same general narrow ratio between leaf area for photosynthesis and volume of those roots that convey organic food to the mineral absorbing organs.

The ratios of leaf width or leaf area of plants low in starch, sugar, and protein production to root volume are different from those of the high energy crops and segregate into several categories depending on a number of circumstances that cannot be developed in this short paper. Plants of low photosynthesizing capacity obviously do not require thickened roots to convey organic food. Cabbage, celery and lettuce have much thinner roots than wheat that bear from the root crown or central branching tap root. Although they have many very fine roots their absorptive capacities are low and richer soil is required for good crops of plants in this classification than is the case with wheat or other high energy plants whose roots are thicker and have greater absorptive power.

Other categories of root to top ratios of plants

A second category of low energy content and low mineral absorption vegetation is rapidly growing species common to warm climate, such as watermelon and other vine crops. Rapid foliar growth limits the amount of photosynthetic materials available to roots, and too high soil temperature might also restrict their growth. The root-leaf features of this group of vegetation are large leaf area and small root volume for organic food. This restricts mineral absorption. The amount of carbohydrates produced by an acre of densely covered vine crop such as watermelon, pumpkin, or tomatoes is small compared to that of wheat, rice, or corn.

A third category of low energy content and low mineral absorption vegetation is typified by one of the worst weeds of agriculture, a convolvulus, commonly known as morning glory or bindweed. It gives the pattern for the root-leaf features for perennials, including trees. Integration of perennials involves consideration of the relation of starch, sugar, and protein to the production of cellulose, a subject that will be treated in other papers. The ratio of root-leaf features of convolvulus are essentially opposite to that of the other low energy group above mentioned. Perennials are dependent on the storage of a large part of the products of photosynthesis for renewed growth the next season. This requires a moderate rate of growth so that photosynthetic products may accumulate for storage. The pernicious habit of convolvulus is its moderate rate of growth whereby much of the products of the leaves are made available to the buds in the roots. The ratios of the root-leaf features of this category of vegetation are those of relatively small photosynthesizing area, and large root volume. Progressive increase in root volume with growth implies additional need for organic food or increase in leaf area. A moderate rate of increase of photosynthesizing area integrates into species with small leaves or a slower rate of growth than those having large foliage. Species having a moderate rate of foliation store more organic food in the roots than those having a high rate.

A fourth category of low energy content vegetation has very high mineral content due to its low rate of vegetative enlargement and long period of mineral absorption which is characteristic of desert vegetation. Integration of this group is oriented from the standpoint that these plants are repositories of inorganic elements rather than of the organic compounds which are the bases for the other categories.

Relations of rate of growth of plants to the production and storage of starch, sugar, and protein

Highest sugar or starch production per plant or per unit area requires a moderate rate of growth of vegetation. Too slow growth limits leaf area, that is photosynthesizing surface, and too rapid growth either of roots or leaves uses the products for vegetative enlargement thus leaving little for storage. Protein production also is influenced by rate of growth, but not as pronouncedly as starch or sugar. Slow growth, small leaves, and highest per cent protein in seedlings—that is, the small statured state of vegetation—are associated phenomena. However, a large amount of protein production per unit area is dependent on con-

tinued growth of plants but too rapid vegetative enlargement dilutes the per cent by increasing the size of the plant—that is the area of production. Within the scope of these circumstances lie the factors for integration of vegetation for form which expresses the plant's adaptation to the circumstances of environment. Form is the means whereby the rate of growth of plants is adjusted to cosmic forces which affect fundamental chemical reactions. Rate of growth integrates into time required for a plant to produce a given amount of starch, sugar, protein, or their equivalents in other botanic products. The conditions whereby the highest amount of starch, sugar or protein are produced are the bases from which other cultural conditions are oriented. Only after mineral absorption, but particularly nitrogen, has declined either by depletion in the soil or by stoppage of new root growth, or unfavorable conditions to vegetative growth, can starch or sugar accumulate in high energy crops. The amount which the plant stores within itself depends on the leaf area and the length of period following the cessation of vegetative growth before the decline of the foliage. Protein does not accumulate in the plant after the absorption of nitrogen ceases—or otherwise expressed, when vegetative enlargement has stopped. The distinction between the conditions for high protein and high starch or sugar production per unit area is that the one is dependent on continued vegetative growth, the other on ample vegetative enlargement during the early growth stage followed by a long period when the leaves are active in photosynthesis only. Protein production is essentially a process of youth of the foliage, that of starch or sugar one of maturity. Protein production can be integrated into the length of time the foliage of a species is in a state of youth, that of sugar or starch into that when foliage is in a state of maturity, but does not include senility.

Plants can be segregated into categories by their root-top features, and species within each group arranged according to gradations based on the relationships that exist between (a) protein and carbohydrate synthesis, (b) protein production and rate of growth of plant, (c) sugar and starch production and rate of growth of plant, (d) protein production and length of the period of vegetative enlargement, (e) sugar and starch production and the length of time leaves are green but do not increase in size or number. The relations these various processes have one to another can be deduced from the conformation of the plants. Using conformation as the basis on which to orient plants for the mineral needs, productive capacities of agricultural crops, and adaptation of species to their environment, vegetative features of plants are the means whereby the correlation of vegetation to its environment is established. Just to give an example of the profound interrelations of growth features in plants, a difference of one hour in the complete life span of two wheat plants of the same variety growing four months was detected by a corresponding difference in the composition of the grain. The higher per cent protein came from the plant which had the shorter life. The law of conformation requires that variation in one feature has a corresponding variation in another character.

The principles brought out in arranging high energy crops of the grass family for their productive capacities of starch, sugar, and protein apply to other categories of vegetation such as legumes, various classes of trees, warm weather plants, cold weather plants, those of low light requirement, those of high light requirement, and other groupings. Plants grown for products other than the primary energy materials, starch, sugar, protein, can not be placed solely by the amounts of these chemical compounds they contain. The relation these basic chemical compounds have to other botanic products, such as cellulose and water—the chief constituents of many species—must be considered in the integration. The dependency of root action on leaf action, and vice-versa, shows itself by distinguishing features. These show how species integrate into unity concepts of characters and of properties.

Wheat—the pattern plant by which other species are measured

The nitrogen requirement of species

A series of books is required to present this subject in completeness but a general idea of it can be obtained by consideration of some of the primary factors which segregate vegetation into categories and these into gradations by the features which express the species' requirements for each element. Integration requires use of features common to all vegetation for each element. The plant which has the greatest absorption gives the pattern of the features of that element which is to be integrated by the modifications which smaller quantities in other species manifest. Wheat has the greatest absorbing power for mineral nutrients

of the plants having the widest geographical distribution and can be taken as the basis from which other species are oriented. The root-leaf features of the crop giving the largest production on record gives the pattern of the mechanism which absorbed about 200 pounds of nitrogen from an acre of ground and produced 7500 pounds of grain. Seed is the chief repository of the nitrogen and phosphorus wheat absorbs. The seed-non seed ratio throws light on the character of the root-leaf dependence of various species and the distribution of nitrogen in the plant. The ratios of seed-non seed tissue cover a very great range among vegetation. Seed outweighs non-seed tissue in some species but in others is a negligible fraction of the weight of the plant. The ratio can be used as a yardstick to segregate vegetation into categories and determine whether or not the plant is an annual. All plants that have a high seed-non seed ratio are annuals but the converse, low seed-non seed ratio does not connote that all species belonging to this category are perennials. Perenniality is dependent on the storage of a considerable quantity of the plants' photosynthetic products, including some proteins, in the roots or in organs that will supply them later with organic food when growth is renewed. Storage of appreciable quantities of materials in other plant parts than seed reflects itself correspondingly by a lower seed-non seed weight ratio.

The amount of nitrogen stored in the seed is determined by the number, size, and composition of the kernels. Other things being equal, as the seed of other species of graminaceous crops increases in size above that of wheat the per cent nitrogen decreases, and as the size decreases the per cent nitrogen increases. The relations between composition and size in seeds of different species if properly grouped is similar to that of leaves. However, conditions are not equal, for diversity is the cause of species, and digression in the character of one feature of a given pattern is associated with covariation in other characters. For example, some rice seed is smaller than wheat, and also lower in protein. The integration of rice by the character of its seed involves the fact that the plant can not absorb as much nitrogen as wheat because of its lack of roots of requisite diameter and spread. Generally a large seed requires a longer time for filling with starch, sugar, or protein than a small seed. It is common knowledge clover seed requires but a fraction of the time from pollination to maturity that corn or wheat does. The factor *time* integrates vegetation having a high seed-non seed ratio into that having a low seed-non seed ratio, or otherwise expressed, is one of the terms required to integrate annuals into perennials.

Similarly, as the conformation of the whole plant is the result of the interplay of various factors, so its parts such as the seed have their own distinctive conformations which likewise are the result of the interplay of various factors which can be integrated. In some cases the characters of comparable parts of species can not be interpreted except through the features of dissimilar parts. The integration of corn and clover by the physical characters of seeds, leaves, or roots only, is inconceivable, but the factor *time* by which species can be integrated for form unifies the diverse characters of these two plants so that they, like the pieces of a great jig saw puzzle, all fit into their proper places to complete the pattern of adaptation of vegetation to its environment.

Seeds of legumes are higher in per cent protein than the non-legumes, but when properly grouped follow the same general pattern as that of the cereal crops in the relation of change in size with per cent nitrogen. Likewise, their leaves when integrated to equal length of growth period follow the same general pattern in these features as that of graminaceous crops. Proper grouping of species is fundamental when arranging plants for their food requirements by one or more features which in themselves do not fully reflect the plants' conformation. Legumes have very wide geographic distribution—some are warm, others cold weather plants—some are annuals, others perennials—some have high, others low light requirement. The diverse characters of the legumes, notwithstanding the beclouding factor of symbiosis of the nitrogen-fixing bacteria, bring out some of the fundamental relations between (a) size and per cent protein, (b) age of plants and per cent protein, (c) length of growth period and per cent protein. The fundamental consideration in the integration of vegetation on the basis of starch, sugar, and protein production per plant and per unit area of earth's surface is to express the relation climate has to the production of these products, or, expressing the matter otherwise, to show how the latitudinal distribution of these products manufactured by different species integrates into the length of the period of favorable light and temperature. The basic pattern on which all vegetation is integrated for its geographic distribution is that the nearer

to the tropics the plant is grown, the longer the period of favorable light and temperature, hence longer growth period, hence more photosynthesis, hence more starch and sugar production per unit area per year. The converse to this is, the more remote from the tropics—that is, the nearer the pole—the shorter the period of favorable light and temperature, hence shorter growing period, hence less photosynthesis, but relatively more protein because short-lived species or annuals would be grown. Annuals are at home in the tropics also, where some have shorter, others longer growth periods, than those in cooler climates. The intensification of photosynthetic processes, which is an element that must be considered in the integration of species to climates, provides a shorter growing period, gives greater production per unit of time than in plants having a long growing period. A climate that favors perennial growth contains an element that operates against the accumulation of starch and sugar, for stoppage of vegetative enlargement is necessary for these products to accumulate as storage material. Stoppage of vegetative enlargement is also necessary for the production of high seed-non seed ratio in vegetation. As seed is higher in nitrogen than in any other part of the plant, it follows that the highest per cent protein a plant would have occurs during its seedling stage. The seedling stage of a plant's growth integrates into small stature vegetation. The greater the enlargement from the seedling stage, or the longer the life of the plant, the greater the decrease in per cent protein from that of its youthful state. The total amount of protein in the plant increases with growth, that is, with the absorption of nitrogen by the roots. When seed is produced, protein becomes localized and a new cycle of reactions begins with a new plant. A high seed-non seed ratio and a large production of seed per unit area by legumes require a moderate rate of vegetative growth. Peas are grown farther north and planted earlier in spring than beans. From the general pattern showing how starch, sugar, and protein production by the graminaceous crops, including sugar cane, vary with latitude, and from the general conditions governing the quantitative relation between protein and carbohydrate synthesis in any plant, the growth pattern for the cool weather peas and the warm weather beans can be deduced. Expressing this in a comparative way, cool weather for peas means slower growth, smaller leaves, smaller seeds which are higher in per cent protein, and lower in per cent starch and sugar than beans. On the other hand cool weather also means longer growth period, hence lower per cent protein, and higher per cent starch and sugar than beans. Furthermore, it could also be interpreted to mean a lower light intensity which could restrict root action and the absorption of nitrogen. Due to these opposing circumstances it follows that some species and varieties of beans are higher in protein or have smaller seeds and leaves than peas. However, when all elements of conformation are considered, variation in one feature from the general growth pattern of a plant, which can only be stated by comparing it with that of another, has compensation in other features. These provide the earmarks by which diverse species can be integrated into unity concepts.

Plants low in starch, sugar, or protein which comprise many diverse species can be arranged in order of their absorptive capacities for nitrogen by the same tokens as the high energy and high protein plants. They are integrated and unified into a pattern which expresses the relation of rate of growth to form. Rate of growth can be used as an expression of the length of time required for the species to reproduce itself in seed or if a perennial store sufficient organic food in the roots for renewed growth the next season. Form integrates species into the chief elements of climate, light and temperature, by which all vegetation is oriented.

The integration of vegetation is based on a series of relations, each of which considered from a purely physical point of view is obvious. They are: The association of (a) rapid growth and large leaves or large size of plants, (b) slow growth and small leaves or small size of plants, (c) rapid growth and short life of plants, (d) slow growth and long life of plants, (e) rapid growth and coarse cellular texture in plants, (f) slow growth and fine cellular texture in plants, (g) rapid growth and little storage of starch and sugar in plants, (h) slow growth and small leaf area, hence little photosynthesis by plants, (i) perennial growth or long period of youth and short period of maturity of plants, (j) annual growth and relatively short periods of youth and of maturity, and others. All of these relations are influenced by cosmic forces chiefly temperature and light, which become expressed by the conformation of the plants.

Placing of the species for their requirements of other nutrients is in principle similar to that of nitrogen, but additional earmarks are required for each element. The nitrogen background is

necessary to orient each species, as it is the only soil element with minor exceptions that is a constituent of protein. The other elements become part of the mechanism which manufactures protein and carbohydrates, but are not raw materials out of which these products are made.

Calcium requirements of species

Calcium does not become localized in plants, consequently a ratio of high calcium-low calcium tissue can not be used as a basis for orientation as in the case of nitrogen. The chief function of calcium is in the structure of cell walls. Conceivably the more cell wall per unit volume of plant tissue, the more calcium the species require. Plants vary in their cell structure. The smaller the cells the more wall tissue is required per unit volume of cellular structure. The mathematical formula for the relation of surface area to volume with change in the diameter of particles gives an index to the ratio of amount of cell wall per unit volume of cellular structure of cells of different sizes. A structure composed of large cells gives a narrow ratio between their surface area and volume, and that composed of small cells has a wide ratio between these features. Wheat, rye and barley, when in full vegetative growth, have many more fine roots than rice, hence wide ratio between root area and root volume. These plants have much higher calcium requirement than rice as shown by the marked injury they suffer in culture solutions devoid of this element. Cabbage, low in protein, carbohydrates, and mineral nutrients, has many fine roots, smaller than those in wheat, and suffers markedly in calcium-free media. Sugar cane and orchard grass, low in per cent protein and fairly high in mineral nutrients, have thick roots which show markedly less injury in calcium deficient solution than plants characterized by high per cent protein or very fine roots. Associated phenomena among vegetation are (a) high protein, fine roots, and high calcium requirement, (b) low protein, low mineral content, very fine roots, and high calcium, (c) low protein, thick roots, and low calcium, (d) plants with pencils of unbranched roots, producing a narrow ratio of root area to root volume, and low calcium requirement, (e) vegetation with thick roots which penetrate deeply into soil layers richer in calcium than the surface stratum, with diverse calcium requirements depending on other features such as the fineness of the deep roots and protein content.

The root structures of plants having high calcium requirements suffer more injury from the lack of this element in the culture media than from that of any other element. As the root systems of species vary with the physical characters of the soil or culture solutions in which they are grown, so their calcium requirements vary. This affects the plant's tolerance for acidity. Many species have greater tolerance for acidity in liquid media than when grown in soils.

Potassium requirements of species

Species are arranged for their potassium requirements by tokens that integrate into the quantities of sugar, starch, and protein they produce. Plants high in any one of these products require more potassium per unit weight of growth than those that are not. The complex conditions under which various quantities of these products by the different species are produced, and the complementary relation between protein and carbohydrate synthesis, preclude placement of the species by their composition only. As the amounts of carbohydrates synthesized are influenced by light conditions, it follows that the plant's potassium requirement varies likewise. Potassium is required for vegetative growth. It has been pointed out that the productions of large amounts of sugar and starch are conditioned by the cessation of vegetative growth to permit these photosynthetic products to accumulate in plants. Certain light conditions can cause excessive vegetative growth and restrict photosynthesis so that starch and sugar do not accumulate in the plants. Such climatic conditions may increase the potassium requirements of plants by one process, but reduce it by another. Such opposing circumstances must be considered in placing species in the order of their potassium needs. The rôle of potassium in turgor and in the movement of water, processes influenced by climate, makes the plant's requirement for this element more subject to meteorological variations than any other of the major nutrients.

Potassium stands next to nitrogen in order of the amounts of nutrients absorbed from the soil except in vegetation adapted to very saline land. This element does not become localized in seed with the maturity of the plant as do nitrogen or phosphorus, consequently, the per cent potassium is lower at the seedling stage of growth than in later life, differing thus from those elements which accumulate in the seed.

The requirements of species for potassium in processes of which the highest performance of one can not occur under conditions essential for that of the other are reflected in root characters. Fine roots of the wheat type which have highest absorption of nitrogen, and the thick ones which convey the organic food of photosynthesis to them, are the elements out of which root characters are made. Thick roots extend the sphere of action of the thin ones. Increase in distance of these from the parts of the plants where they are used lowers their efficiency as food supplying organs. This affects the plant's potassium requirement as well as that of other elements from the standpoint of supply of the soil. Many combinations of these two elements of structure, thin and thick roots, are manifested by species. Diverse root structures are the adaptive features of diverse foliar structures.

It was pointed out that the ratio of leaf width to root diameter, or leaf area to root volume, was narrow among the high energy content species and that the ratio between these features was wide or otherwise distinctive in all of the low energy content plants. Within the scope of these relations lies the basis for arranging species for their potassium requirement. The amount of protein necessary for the production of a unit quantity of starch or sugar, and vice-versa, which varies among species, is a fundamental consideration in integrating plants for their potassium needs. The differences among species integrate into form, because of the relations rates of growth have to photosynthesis and the storage of starch and sugar. Other things being equal, the greater the production of protein, starch, and sugar per plant, or per unit area of earth's surface, the more potassium is required. As the amount of these products species produce would vary according to climatic factors, it follows that the potassium requirement would not be constant.

Magnesium requirements of species

Placing species according to their requirements for magnesium requires the background of the features associated with nitrogen, calcium, and phosphorus. Magnesium is a constituent of chlorophyll. It is also stored in the seed. The per cent is higher in the seeds high in protein than in those low in this product. In some species seed is richer in magnesium than in any other part of the plant, in others not. This places magnesium in another category from nitrogen and phosphorus, which becomes localized in seed, and from calcium and potassium, which do not. Increase in leaf size among species connotes more magnesium for chlorophyll. Increase in per cent protein of seeds among species indicates correspondingly greater calcium and phosphorus requirements and, therefore, more magnesium. Increase of leaf size and per cent protein stand inversely related to each other so that the magnesium requirement of plants can be considered a balance between opposing circumstances. The lack of an element in culture solution whose function is for processes located wholly in the leaves, as is magnesium, has its counterpart in relatively more root growth than top growth. This gives the plants larger root-top ratio than where magnesium is available. This affects the composition of plants, which become richer in nitrogen and other elements than would be the case if magnesium were available. This explains some of the apparently inconsistent phenomena concerning the rôle of magnesium and the coloration of leaves. In some species lack of the element in the culture media is reflected in etiolation of the leaves, but in others deepens the green color. Species reflect gradations between opposing circumstances. Their diverse features may be considered as links of different sizes in the continuity chain of plant conformation. If a link is long, it also is narrow. Compensatory measurements are considered in using a plant feature as an indicator of the species requirement of an element. Provided the per cent chlorophyll does not change increase in leaf size among species means more magnesium. However, it also means more photosynthesis, and its converse, less protein. Thus, opposing factors determine the features by which the plants' requirement for magnesium is evaluated. The features are interpreted when resolved into their elemental components. Whether increase in leaf size and decrease in protein, or vice-versa, increase in protein and decrease in leaf size, was the more important consideration in determining a plant's requirement for magnesium is indicated by the shape and place of the link in the chain of continuity of species in plant conformation.

Phosphorus requirements of species

The placement of species in order of the quantities of phosphorus needed per unit weight of production requires the background of the features which indicate the plant's requirement for nitrogen

and calcium, also those which express the function of the element in the formation of nuclear proteids. Seed is higher in phosphorus than in other tissue, and thus the highest per cent in a growing plant would be found in the seedling stage. As the plant enlarges, the per cent decreases, but as growth is dependent on the absorption of more phosphorus the rate of decrease is not the mere complement of increase in size. Rates of absorption of phosphorus, and any other element, and vegetative enlargement are distinctive in their relationship one to another. The absorption of an element is dependent on that of other essential nutrients in the making of the normal plant which is distinctive in all of its phases of growth. The highest per cent of phosphorus in the seedling state of conformation, and the lowest at maturity state are the end points of a chain of gradations, each of which is distinctive in the general pattern of progressive change of plant conformation. The ratios of (a) girth to height of plant, (b) number of leaf buds to height of stem, (c) number of starting points for new roots to size of plant, are greatest in the seedling state of development. The ratios decrease as the per cent of phosphorus decreases with the age of plants. This gives the prototype for differences in the phosphorus requirements of species.

Plants having high protein and calcium requirements absorb more phosphorus than those low in this character. This relationship associates differences among plants in their absorptive capacities for phosphorus with those distinctive root characters that segregate species into groups for their nitrogen and calcium requirements. However, root characters alone are not sufficient to place all species. The range of variation in per cent phosphorus in the seed of a species is less than that of nitrogen, but may be greater in the non seed tissue. The absorption of phosphorus is not as closely adjusted to the physiological requirements of various processes of growth as nitrogen, and plants may absorb more than they need. The relation of excess absorption of an element to conformation is considered in the placement of species, but this subject is too long to be discussed in a short paper.

When the amount of phosphorus required for the maximum yield of wheat per acre is absorbed by an equal area of corn, the per cent in the plant is lower, because of the greater size. Corn absorbs more phosphorus than wheat so that the smaller per cent in the plant is associated with a larger quantity removed from the acre. The same quantity in smaller plants would be reflected by a larger per cent of the weight of the vegetation, and by the features or conformation of the smaller plants. Similar principles hold for the relationship of composition to size in varieties but in order to place them for their capacities to absorb phosphorus, all elements of conformation must be used. The features of species and varieties are unified by integrating them to equality. Without integration, species are many ontogenies, but by integration they are merely different amounts of mineral nutrients absorbed by roots, and different amounts of photosynthesis by leaves for equal units of time. In order to place species according to the amounts of phosphorus they require per unit weight of growth, the features which indicate their requirements for nitrogen and calcium are integrated to show how these elements are related to the number of growing points species have. The more branches, leaves, and seeds per unit length of stem and the more root branches per unit length of main root, the more phosphorus species require.

Requirements for other elements

Species can be placed in order of their requirements for sulfur and iron by distinctive features.

The functions of the minor elements boron, manganese, zinc, and copper are not sufficiently clear to place species for their requirements of each of these elements. It is known that they vary and that climate affects the amount certain plants require of the various minor elements.

Mechanism of absorption and selection of elements by plants

The relation between thickness of roots and the quantities and qualities of elements absorbed suggests that the mechanism of selective absorption might be in the size of cells. Normally, the rapidly growing thick roots would have a coarser cellular structure than the slower growing fine roots. Nutrients are absorbed primarily in solution, but entry into plants of minute quantities of ions by emanation is not precluded. Osmosis conveys nutrients with water as it passes from the dilute soil solution to a more concentrated root sap. Osmosis varies with the concentration of cell sap and not with the thickness of root, hence, would not explain the selective absorption noted in the species of different root sizes. Nutrients can also enter with capillary movement of liquids along solid surfaces and the walls of porous bodies, such as plant cells. Movement of liquid by capillary

attraction in cellular structure orients the surface attraction forces according to the arrangement of the walls. The attraction of opposite walls of the cells for their fluid contents creates a boundary zone between liquid films where the resistance to the entry of materials is lowered by the pull of opposing forces. This affects the permeability of the wall and may allow ions that are not too large to pass through. Size and shape of cells determine the orientation of capillary attraction forces and the character of the boundary zone between opposing pulls. Histological data on roots of species are too incomplete to arrange plants by their cell patterns for correlation of the molecular dimensions of the nutrient elements with the character and orientation of surface tension forces in cell structure. The property of roots to absorb some elements and not others may conceivably show correspondence with cell size. Elements that enter would be of a size to conform to this boundary zone. The very large cells of species having thick, rapidly growing roots would have their walls too far apart from the opposing pulls to affect the permeability of the walls in the boundary zone. Very small cells would not have a boundary zone of adequate size to permit nutrients to pass through them. The fact that the greatest absorption of mineral nutrients by plants is not obtained by the thick roots or by very fine roots having a great absorbing surface is of consequence. Selective absorption of nutrients by plants appears to be a function of cell size.

Balance between opposing circumstances

The integration of vegetation for form brings out the relation and balance which opposing circumstances have on growth and accounts for the characters of species in their latitudinal and elevational distribution. Increase in temperature with the lengthening days of late winter and early spring and the decrease with the shortening days of late fall have two opposing factors affecting the root-top ratio of growth in plants. This meterological effect is reflected geographically in the change in the root-top ratio of vegetation with latitude. The approach to the tropics tends to cause a low root-top ratio by virtue of increase in temperature, but a high ratio by that of light. The approach to the pole tends to cause a high root-top ratio by virtue of lower temperature, and a low ratio by that of light. Due to the inclination of the earth's axis, light becomes favorable to growth in spring before temperature does, and remains so, longer in autumn. The nearer the pole the more pronounced are these circumstances with the change of seasons. They reach their climax in the longest days of sunshine of the short season of favorable temperature in the highest latitude vegetation grows. The integration of vegetation for form is oriented on the minimum time required for species to reproduce themselves by seed, or if perennials, by the storage of organic food needed for renewed growth the next season. Form integrates into the size the species attains within the time conditions are favorable to growth. Form, size, and length of growth are interrelated and interdependent one upon the other. For example, wheat and barley can reproduce themselves by viable seed in about six weeks after the seed is planted, or can require about ten months, depending on temperature and light conditions, and also at all gradations between these extremes. Obviously, wheat or barley plants that complete their entire growth cycle in six weeks are smaller and of different conformation than those which required longer time. Length of growth integrates into size and form, and each of these characters into the other. Light and temperature affect size, form, and length of growth period of species differently, as some have small, others large amplitude in which to adjust their growth cycles to the prevailing circumstances. Size and form integrate into rates of growth which integrate into the cosmic forces, temperature and light. Form, adaptation, mineral absorption, photosynthesis, and production of agricultural crops per unit area of surface exposed to sunlight are interrelated phenomena. The integration of vegetation for one of these subjects aids in that of another. None can be completely integrated without the other.

Hydroponics provided another ecology which made differentiation of edaphic and meteorological factors affecting plant growth possible

Hydroponics has provided the key to the source of, and the avenue for, the information needed to proceed with, and to complete the integration and the ordination of vegetation into unity concepts of each of the above subjects. This is a comprehensive undertaking. That soilless crop-production became the means to integrate soil vegetation is due to the fact that hydroponics provided a different ecologic basis and background than that

on which all vegetation is oriented. It was impossible with soil grown vegetation to differentiate edaphic and meteorological factors on growth. Only by the elimination of the soil in crop-production could the edaphic and meteorological factors be evaluated independent of each other. Plants have been grown extensively in small containers of nutrient solution for experimental studies in scientific laboratories since 1860. The primary object of these experiments, and the goal of soil science, generally, was to give chemical interpretation of the ways and means soils make plant foods available, and explain how vegetation uses them. The methods of study projected the nutritional features of plant growth into the foreground and relegated the climatic factors, which held the key to the origin and adaptation of species to their environments, into the background. Climate affects vegetation through the physical properties of the materials with which it is in contact. Those used in hydroponics may have markedly different climatic and ecologic effects than soil. Essentially hydroponics created a new order of climatic and ecologic environment in the culture of vegetation, which, like that of soil, is the basis on which the mineral nutrition of plants for water culture is oriented. A few degrees of temperature segregates the vegetation of different climatic zones. Because materials of low specific heat, such as vegetable litter used in hydroponic seed beds, would change in temperature quickly, certain orders of solar radiation can have categoric effects on vegetation grown by hydroponics that would not be the case with soil.

It is the ecology of root growth in liquid media that makes hydroponics a new science. Roots segregate plants into categories. Changes in the root types of species reflect themselves by other features. Liquid media markedly affect the root types of species by the elimination or restriction of features which make them different, such as thick storage roots, thus tending to make plants alike in their absorptive organs. This change of root types reflects itself in the much greater similarity of mineral composition of different species grown together in the same nutrient solution, than when grown together in the same soil. The fact that many species will grow equally well in the same nutrient solution but not in the same soil is further evidence that the change in root types will have corresponding effects in other features of the plants. The mineral and climatic requirements of the plants vary with their root types which are the expressions of the adaptation of species to diverse soil and climate. The complete elimination of these diversities would project the plants to the influence of their original environment, that is, marine habitation. Root producing vegetation is autochthonous. As roots hold the key to the evolutionary adaptation of marine species to soil, so likewise, they hold it for cultural adaptation of autochthonous vegetation to hydroponics. The evolutionary history of vegetation from a pre-root state of marine habitation to the large roots of large trees growing at high elevation with its great extremes in climate aids in ordering vegetation for adaptation to hydroponics. When land species are grown in liquid media the root systems become markedly unified, as the thickest and the thinnest, the longest and the most branched organs, characteristic of their soil habitation, do not form in water. The significance and implication of an altered root system on the physiology of water grown vegetation is far reaching. The magnitude of change species undergo from soil to hydroponic habitation, and the amplitude of change they can undergo without harmful effects give the physiological background on which plants are ordered for water culture. Species can be integrated for hydroponic culture by root-top features for form, adaptation, mineral absorption, photosynthesis, production per unit area of earth's surface, similar as for their soil habitation. They segregate into categories for which appropriate cultural technique and conditions must be provided in order to grow them successfully without soil. A series of books, one of which is published, (*Complete Guide to Soilless Gardening*, 1940: Prentice-Hall, *New York;* Putnam, *London*. See also articles on Hydroponics, *Encyclopaedia Britannica Year Books*, 1939 and 1942), others being in the making, are required to formulate this subject into a useful compendium for those who wish to grow crops by this method. Mastery of the art and science of growing crops without soil consists in a great measure in understanding plants from the standpoint of ecology, which is different from that of agriculture.

The root-top weight ratio of plants grown by hydroponics is less than that of soil. This is significant in practical production, as the margin of safety and assurance against the event of untoward conditions arising is much less than with crops grown in soil. On the other hand, it has its advantages as plants having a low root-top ratio can be placed closer, giving a larger produc-

tion per unit area than in soil, provided the cultural technique is arranged wisely within the smaller amplitude of highly favorable circumstances to plant growth which water culture permits. A cubic foot of nutrient solution contains from three to six times more available water than a similar volume of various soils, therefore, certain crops such as potatoes and corn can be planted closer than in agriculture with corresponding increases in yield. There are crops that can not be planted closer in hydroponics than in soil because of the limitations of light, and there are species whose root structures make them unsuitable for water culture. In hydroponics, stand is determined primarily by light considerations; in agriculture it is by the amount of nutrients available in the soil. The area of earth's surface having favorable light and temperature for crop production is much greater than the area of arable land. Hydroponics can outyield agriculture both in the production per unit area for certain crops and in the extent of area where it can be employed. A discussion of the economics of this method of production is outside of the pale of this paper, but from the elements that determine cost it is evident that hydroponics will be an economic competitor to agriculture in some important lines of production.

Hydroponics has introduced some new problems of physiology and ecology arising out of the root action of plants, which affect the immediate surrounding climate more than in the case of soil grown vegetation. The plants lose more water by guttation—liquid issuing from the tips of leaves —which can have either harmful or beneficial effects, depending on circumstances. Great loss of water by guttation in greenhouses during winter can add to the burden of disease control, but air conditioning can overcome much of this difficulty. This property of plants, on the other hand, provides a natural means of air conditioning homes by providing more moisture in the atmosphere, especially desirable in winter when the air has become too dry from heating. Species vary in their transpiring and guttating power according to the characters of their leaves and roots. Vegetation can be integrated for its climate influencing properties by features that show the nature of the dependence of these organs one on another for intake and loss of water. Other properties of plants made manifest by hydroponics open new avenues to human interest. These, with those just mentioned, appear to herald an age when much smaller space and less mechanical and industrial organization will be required for man to enjoy his dependence on his own vine and fig tree.

Evolution of plants clarified by hydroponics

As hydroponics has provided a key for the integration of existing vegetation so likewise it has provided a key that will unravel some of the evolutionary history of past floras. The changes which the roots of species undergo in water culture from that of their soil types are *reversion* to primitive states in which they existed in their evolution from an original marine habitation through different stages of soil ecology consisting of marshes, lowlands, and highlands to the present status of land habitation with its great diversities of climate. Species adapted to uplands with great diversities of climate undergo much greater change in hydroponic culture than those adapted to lowlands with equable climate. Using integration as the means to arrange species for their evolutionary history, it can be shown that the vegetation of any geologic period, whose fossil remains or products are in existence, did not produce as much protein, or starch, or sugar, or cellulose, or lignin, or any plant product containing fixed carbon, or absorb as much of the soil minerals per unit weight of plant, per unit area of earth's surface, per unit of time than does the vegetation of today. The forms and features of past floras, the characters of the soils on which they grew, the kind of climate to which they were exposed, and some of the characters and features of the animals whose food these plants were, all unfold themselves by integration into a panorama of evolution where individual features can be deduced and evaluated by the relationship they as parts hold to others of an ordered cosmogony and a defined cosmography.

Comparison of the rate of carbon fixation by plants today with that of geologic times can be obtained by estimating the amount of coal which would be formed by the most rapidly growing species if such carbonization processes were possible now. More than one million board feet of lumber has been obtained per acre from some of the best stands of California coast redwood (sequoia sempervirens) averaging 500 years in age. This amount covers an acre with solid lumber 23 feet deep. Lumbermen state that about one half of the volume of these trees is used as lumber. Thus, the actual amount of woody tissue produced in 500 years would cover an acre twice the above figure. The density of bituminous coal ranges

from 1.2 to 1.5, and the best grades are from 80 to 90 per cent carbon. The density of redwood ranges from 0.7 to about 1.00 and pure cellulose is 40 per cent carbon. Four cubic feet of fairly dense redwood contains as much or more carbon than the average solid cubic foot of good bituminous coal. Forty generations of redwood, one succeeding another every 500 years, at the above rate of growth, continued for 20,000 years, would fix enough carbon in woody tissue to create a coal seam 500 feet thick which is more than the summation of the known coal seams laid down in geologic history, estimated at many millions of years. It is to be noted that these figures do not include the roots which in redwood range from 30 to 40 per cent of the weight of the tree when in active growth of vigorous youth.

Integration clarifies the properties of vegetation which became coal and explains why most dead vegetal tissue does not undergo carbonization today. Microorganisms cause disintegration of plant tissues which contain protein, starch, sugar and other materials as food to sustain their activities. These food materials for micro organisms were either lacking or present in insufficient quantities in ancient floras, hence they did not decay when dead, thus permitting accumulations of great thickness of vegetal material to be eventually submerged by water or soil or both for ultimate carbonization and solidification. Geologic plants did not have the kind of roots which were capable of high absorption of essential mineral nutrients, hence, they could not produce a foliage capable of the high rates of photosynthesis of today, and vice-versa, the photosynthesis then was not capable of sustaining a large root system. Ancient soils were not of a character conducive to produce a root system of high absorptive capacity of those elements necessary for high production. Also the genetic constitution of that vegetation was not developed to encompass physiological functions at high rates. Geologic history can be unravelled by the rate of change in the physical features of plants in past ages which can be mathematically deduced, and employed in integration. This integration employs differentials derived from the projection of progressions of features and conditions which are known or can be experimentally established, and carries them to the ultimate goal.

Erroneous views concerning determining factors in soilless crop-production

Hydroponics has suffered harm and violence from misinformation, misconceptions, and various half-truths. Terms like *chemical gardening, chemical farming, chemiculture, nutrient culture, magic gardening*, etc. which directed attention to, and gave emphasis on the nutritional features of water culture, thereby relegating the far reaching, and determining factors of ecology which the new system and its equipment created, into the background, were most unfortunate. Books, bulletins, and reports have been published purporting to give directions on soilless plant culture without such important words as *climate*, or *ecology*, or any of the concepts they imply, appearing on their printed pages. It is probable that no individual has tested more chemical combinations in nutrient solutions for plant culture in laboratory studies along classical lines, and used greater numbers of cultures and species than the author, but the information that was most helpful to him in originating and establishing soilless crop-production came from observation and studies of plants in Nature's outdoor workshop. A naturalist's point of view was necessary to complement and fulfill the essence of a development that remained hidden in three quarters of a century's experimentation with water culture in academic studies. Practical working knowledge is made possible for all and the science of hydroponics is formulated by the integration of species, both for soil and for water culture. Integration answers questions of plant physiology and ecology which could not be resolved by other methods.

NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of Biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY *can notice in this department only such as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to B. H. Willier, Editor of* THE QUARTERLY REVIEW OF BIOLOGY, *Department of Biology, Homewood Campus, The Johns Hopkins University, Baltimore, Maryland, U.S. A.*

BRIEF NOTICES

EVOLUTION

THE UPPER ORDOVICIAN FAUNA OF FROBISHER BAY' BAFFIN LAND. *Geology, Memoirs Field Museum of Natural History, Volume 2.*

By Sharat Kumar Roy. Field Museum Press, Chicago. $3.50. 12½ x 9⅝; 212; 1941 (paper).

The records and material forming the basis of this report were collected during the season 1927 and 1928 by the geologist of the Rawson-MacMillan Expedition of the Field Museum to Labrador and Baffin Land. Baffin Land is a large, long, irregularly-shaped area lying above Labrador between northeast Canada and Greenland, closer to the Canadian shores, however, than to Greenland. Frobisher Bay, a deep indentation at the southeastern extremity of Baffin Land, and once thought to be the passage from the Atlantic to the Pacific, was the final destination of the Field Museum Expedition. The expedition was organized to spend two summers and a winter cruising in the coastal waters of Labrador and Frobisher Bay, making observations and collections relating to anthropology, botany, geology and zoology. For the geologist, Silliman's Fossil Mount, at the upper reaches of Frobisher Bay and the only sedimentary formation throughout this entire region, was the chief field of exploration.

In an introductory chapter the author gives an interesting outline of the journey. Three excellent maps furnish the reader with a clear picture of the numerous points touched. Fossils totalling to 92 species have been collected from the Mount, an isolated hill of limestone lying upon pre-Cambrian rocks, on three previous occasions. The much larger Field collection consists of 68 genera with 116 species, but Roy does not consider that he obtained all the forms present. The approach of winter hastened the expedition on its way. Among the forms listed are Receptaculites, corals, cystoid and crinoid, bryozoans, brachiopods, pelecypods gastropods, cephalopods, trilobites, and ostracods. These are all described in detail and illustrated. In a "Synopsis of Fauna" Roy gives the geologic ranges of North American and Greenland species allied to those from Silliman's Fossil Mount. There is also a discussion of previous collections from the Mount and an interpretation of the age of the fossil area. Regarding the age the author says:

> The question at issue is whether the fossils from Silliman's Fossil Mount represent the Mohawkian (Black River and Trenton) or the Richmond or both.
>
> . . . . . .
>
> The above statements afford the basis to conclude clearly that the Silliman's Fossil Mount fauna and its equivalents are a recurring Mohawkian fauna of early Richmond age. The facts that the elements with Mohawkian affinities in these faunas are rarely conspecific with typical Mohawkian species and that these faunas contain a considerable number of unquestioned Richmondian forms are alone sufficient evidence to arrive at such a conclusion.

On the northeast coast of Labrador, 22 drift fossils, representing four genera and six species of Hormotoma, indicate a much wider distribution of the northern Canadian faunas than was formerly thought.

The volume is beautifully printed and illustrated with many excellent photographs and figures and concludes with a bibliography of seven pages and a detailed index.

TRANSACTIONS OF THE AMERICAN PHILOSOPHICAL SOCIETY. *New Series, Volume XXXI, Part V.* Papers as follows: *The Anatomy of the Pelecypod Family Arcidae*, by Harold Heath. *The Brain and Its Rôle in the Phylogenetic Transformation of the Human Skull*, by Franz Weidenreich. *Phylogenetic and Cytological Studies in the Ranunculaceae*, by Walton C. Gregory.

The American Philosophical Society, Philadelphia. $3.00. 11¾ x 9; 287–520 + 34 plates; 1941 (paper).

The family Arcidae (Ark-shells) is estimated to include not less than 1200 species, the majority of which are fossil forms and have been classified, as have many

recent species, on the basis of shell characteristics. Thirty-two species and subspecies are described by Heath. The author does not modify the existing scheme of classification but in the Résumé he discusses the changes that seem to be in order since "a scheme of classification based upon shell characters alone may lead to erroneous conclusions. . . ." It is "equally evident that comparisons based upon a single organ or system may also prove to be untrustworthy." Twenty-two plates (6–15 figures each) illustrate many of the diagnostic features.

In the second paper Weidenreich finds that

> Cranial sutures in recent man show a tendency to fuse relatively late in life when compared with anthropoids in which they close and even become partly obliterated shortly after the second dentition is completed. The suture of all the three adult *Pithecanthropus* skulls now available . . . exhibits such a state of closure as is scarcely attained in recent man, or if at all, at a rather advanced age.

An interesting comparison is made with the forms and proportions of the skull of the dwarf and large dog and other mammals, and the effect of the enlargement of the brain case and the reduction of the face on the palate and dental arch. We can only quote briefly some of Weidenreich's conclusions:

> The phylogenetic evolution of the human skull is characterized by a continuous enlargement of the brain. The morphological effect of this enlargement corresponds completely in principles and details to that which is seen in the dwarf dog, as a consequence of its relatively larger brain.
>
> The phylogenetic evolution of man, at least in its late phases is characterized by the absolute increase in brain size. The brain size, therefore, represents a character of the first order but all the peculiarities of cranium and face which result from the enlargement of the brain and are generally considered the most essential indicators of evolutionary progress are characters only of the second order. . . . Since the enlargement of the brain appears as the inducing cause of other morphological alterations, the question is justified as to which general factor may now be made responsible for this enlargement. . . . [It] is certainly in some way connected with the adoption of the erect posture and the corresponding transformation of the entire skeleton.
>
> All the facts imply that phylogenetic evolution of man proceeds under the form of an orthogenetic development.

Forty-one tables of measurements and 56 figures are included in the text.

The last paper is concerned with the reclassification of the Ranunculaceae from the cytological standpoint. Type and number of chromosomes have been examined in 19 genera and 108 species. These results are given, and camera-lucida drawings of the chromosomes of all the species studied are arranged in 12 plates with 132 figures. The effect of polyploidy in the evolution versus the speciation of the family is discussed. A phyletic rearrangement of the genera and tribes of the family has been made on the basis of chromosome-type, size, and basic chromosome numbers of the family. On the same data a polyphyletic origin of the various tribes of the family from some ancestral group has been suggested and has been illustrated by phylogenetic charts comparing the classical and the author's classifications.

All three papers are provided with reference lists.

MAN AND THE VERTEBRATES. *Third Edition, Revised. By Alfred Sherwood Romer. The University of Chicago Press, Chicago.* $3.50. 8 x 6½; viii + 405; 1941.

This book, since its publication in 1933, has found wide use as a text and reference book for college students in biology. It presents in a most interesting manner, an easily readable account of the origin and evolution of the vertebrates and a rather detailed survey of the structure and relationships of the primates and man. Although written with a minimum of technical language and detail, the work is comprehensive and authoritative and its usefulness is greatly enhanced by the excellent figures with which it is profusely illustrated.

This, the third edition, has undergone some revision and much new material has been added. One notable addition is the interpolation of a chapter on the anatomy of the frog designed to accompany laboratory dissection of this animal. The chapters dealing with fossil man and human races have been considerably altered and expanded and the sections on higher fishes have been completely rewritten. The material has been brought up to date by the introduction of discussions of new developments in the field, as for example, the recent discovery of a living coelacanth off the South African coast. An appendix giving a synoptic classification of the vertebrates and several phylogenetic trees has been added.

The format of the book has been greatly improved in this edition by having it reset in a more modern style and typography. The number of figures has been greatly increased and the excellence of the photographic illustrations has been brought out by printing them as plates rather than as text-figures. These plates are distributed in groups throughout the book. Unfortunately, the illustrations are not numbered, so that exact reference to them in the text is not possible. Since a single group of plates may deal with several different subjects which are discussed in separate portions of the text, the lack of figure numbers does seem to hamper the author in making full use of the illustrative material in the course of his discussions. It must be said, however, that this disadvantage is not serious and it is in fact partially offset by very full explanations in connection with each figure. The

former editions of Romer were excellent, the present one is even better.

THE MAMMALIAN FAUNA OF THE WHITE RIVER OLIGOCENE. *Part V. Perissodactyla, by William Berrymen Scott. Transactions of the American Philosophical Society Held at Philadelphia for Promoting Useful Knowledge. New Series, Volume XXVIII, Part V.*

By William B. Scott and Glenn L. Jepsen. American Philosophical Society, Philadelphia. $3.00. 11¼ x 9; 747–980 + 22 plates; 1941 (paper).

Part V of this fine series of *Mammalian Fauna of the White River Oligocene* completes Volume XXVIII of *The Transactions*. Two suborders make up the order of Perissodactyla represented in the White River—the Chelopoda, normal perissodactyls with hoofs, and the Ancylopoda, in which the hoofs have been converted into claws. In modern times only three families of perissodactyls exist—horses, tapirs, and rhinoceroses. The old Tertiary of North America and Eastern Asia were the principal regions of perissodactyl development. Eight families are represented in the White River beds. Of these the brontotheres and helaletids came to an end within the White River age. The clawed perissodactyls are not found in North America after the upper Miocene.

The rhinoceroses reached their culminating point in development in North America in the White River, where they are represented by three families, and show more diversification than at any subsequent stage. They disappeared in the lower Pliocene. The tapirs are represented by a single family and genus in the White River and do not occur in abundance. However, Scott points out that their scarcity may be more apparent than real, due to conditions of fossilization, for they were probably then, as now, solitary forest dwellers. They persisted to the close of the Pleistocene. Horses during the Oligocene "were in a state of extraordinary development and diversification and that at a time when the family is not known to have been represented in any other continent. White River horses are surprisingly diverse, whether the many different forms are ranked as genera, species, or geographical races." In their evolutionary history horses are almost at the half-way stage in the White River beds.

Altogether Scott lists and describes about 75 forms of perissodactyls. Measurement lists, tabular matter, 157 text figures, and 22 plates are included. Part V also carries the table of contents and the index to the complete volume.

PALEOZOIC GASTROPOD GENOTYPES. *Geological Society of America Special Papers Number 32.*

By J. Brookes Knight. Geological Society of America, New York. $4.50. 9¾ x 6⅛; vi + 406 + 96 plates; 1941 (paper).

It is a good thing that some devotees of science are satisfied to give their time and energy to producing works of this sort. The digging up of ancient documents that have no merit whatever except age is tiresome in the extreme, but it is necessary in order to clear up the mass of nomenclatorial tangles that still seem to be accumulating faster than they can be assimilated. The only satisfaction that an author can take in a product of this nature is that he is smoothing the path for others who will come after him. That this kind of work is necessary is the result of carelessness on the part of other workers.

The present volume lists in alphabetic order over 500 generic terms, together with full synonymy and type designations. Where there has been more than one designation in the same genus, the reason for the selection is given as well as the present location of the original type specimen, if it is known. Similar works are urgently needed for the Mesozoic and Cenozoic and recent genera.

The 96 full-page photographic plates, the 7-page index, and the 28 pages of introductory material add greatly to the value of the volume.

In passing, it may be noted that the word "genotype" is of faulty etymology. Berry has pointed out that it should have been "generitype." The fact that this term is in use in genetics as the antithesis of "phenotype" makes the change of spelling of the taxonomic term desirable, but taxonomists are likely to adhere to the present spelling on the basis of their fifty-years priority over the geneticists.

GENETICS

MEDICAL GENETICS. *A Series of Lectures Presented to the Medical Schools of Duke University, Wake Forest College, and the University of North Carolina.*

By Laurence H. Snyder. Duke University Press, Durham, N. C. $1.50. 7⅛ x 5⅛; viii + 130; 1941.

A result of a series of lectures delivered at the medical schools of Duke University and the University of North Carolina, Snyder's book is a condensed and remarkably clear survey of the present-day knowledge of hereditary pathological conditions in man. The author is convinced that, in spite of its incipient condition, medical genetics already is of practical value to the physician. The didactic qualities of his short account will undoubtedly help to convince the reader of the correctness of his view. The book will be appreciated, however, not only by readers whose main interest lies in the practical, more specifically medical aspect of genetics but by all students and teachers of genetics.

The latter will find it a useful addition to the existing sources of orienting information.

After presenting in the introductory chapter the various possible applications of medical genetics, explaining the generality of genetic principles and doing away with some traditional misconceptions concerning human heredity, the author proceeds to present two extreme categories of hereditary characters in man: (a) blood groups and blood types (Chapter 2: Medico-legal applications) as clear-cut cases of mendelian inheritance, and (b) mental disorders (Chapter 3) as intricate results of interaction between genetic and environmental factors. In the following six chapters pathological conditions controlled by heredity are discussed, system by system: Eye and ear abnormalities, Abnormalities of the skin, Skeletal and muscular abnormalities, Diatheses and susceptibilities, Diseases of the blood, and Cancer. In each of these chapters the descriptions of symptoms of different pathological conditions are accompanied by suggestions of the possible practical applications (diagnosis, preventive measures, advice on prospective marriages and pregnancies, etc.). The concluding chapter, The future development of medical genetics, deals mainly with the importance of further studies of linkage in man.

The book is well illustrated. The bibliography is too short for a book which undoubtedly will incite many readers to widen their knowledge by looking into the original papers mentioned in the text.

GENERAL BIOLOGY

THE FOUNDATIONS OF CONSERVATION EDUCATION. *Education in Conservation: Pamphlet No. 3.*

By the Committee on Conservation Education. National Wildlife Federation. Washington, D. C. 60 cents (paper); $1.00 (cloth). 7⅜ x 4¾; vi + 242; 1941.

This book is extremely timely. While most of those nations which we formerly called civilized are striving to outdo each other in the rush to immolate themselves irrevocably in the insane holocaust, there yet remains a sober-minded "remnant in Israel" who dare to discuss conservation—the preservation of those values whose destruction is one of the aims of modern warfare.

The book consists of a foreword and six essays—perhaps it would be more appropriate to call them sermons, for they all have a pedagogical and a scriptural flavor. One frequently meets the inevitable text about making the desert blossom as the rose, but the reader is reminded that even a blossoming desert is not necessarily an unmixed blessing, if the blossoms are evoked by artificial irrigation. To obtain water for irrigation dams must be built, which may involve the flooding of valuable forest land, or the obliteration of spawning ground of food fish. It is not enough to urge conservation; the indispensibility of intelligent oversight must be stressed, for conservation, like liberty and charity, has had multitudinous sins committed in its name.

A more significant text which one contributor leans upon heavily, is the description of the promised land into which Moses was permitted to look from the summit of Mt. Nebo, which was flowing with milk, honey, and olive oil, which had fountains in its valleys, and whose every occupant had his own vine and fig tree. But when Jeremiah saw the same land a few centuries later, its springs were dried up, its cedars fallen, its herds scattered, and its cities devastated—the result of uncontrolled erosion and heedless exploitation of its resources.

It must be conceded of course, that between the day of Moses and that of Jeremiah the Hebrews had indulged in a long series of exhaustive wars, during which they and their enemies took turns pushing each other backward and forward from Dan to Beersheba. But the isolation of Judaea cannot be charged to war alone. The fact is that war and devastation of natural resources go hand in hand. As one contributor to this symposium expresses it: "Never do men exploit natural resources so recklessly as when they are fighting or preparing to fight if necessary. Of all human activities warfare is the most wasteful of materials snatched from the earth as well as most wasteful of lives. The short-run wastage rises to its maximum and the long-run depletion goes unheeded." It is not owing to any hyper-fertility of its soil that Lancaster county owes its position as the richest agricultural community in the union, but the fact that its population is descended from industrious ancestors who settled in Pennsylvania to escape compulsory military service in the old country.

Of course the compilation of this book was not undertaken in order to disseminate peace propaganda. The authors are simply not blind to the facts, as another quotation indicates:

> Whether we set out to destroy predatory animals and end by injuring other living resources which contribute an important part of our food supply, or whether presently we set out by force to destroy the enemies of democracy and end by ensnaring ourselves in dictatorship at home, the effect is the same. We have in either case failed by neglecting to think through to the ultimate result and instead we have submitted to an emotional appeal such as so often dulls the logic of any situation and leads to making ourselves and our children the eventual victims.

ANNUAL REPORT OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION *Showing the Operations, Expenditures, and Condition of the Institution for the Year Ended June 30, 1940. Publication 3606.*

Smithsonian Institution. U. S. Government Printing Office, Washington. $1.50. 9⅛ x 5¾; xiii + 512 + 107 plates; 1941.

As is customary, this report includes, besides the report of the Secretary on the expenditures of the Institution and its projects, a group of papers on timely subjects. The general reader is more or less familiar with most of these subjects through magazine and newspaper accounts, but such accounts are frequently "rewrites" by persons without a scientific background. Within the present report will be found a group of extremely interesting, authentic discussions in the field of science, mainly biological, prepared by outstanding investigators and students. In a limited space we can only list a few of these: Solar prominences in motion; The national standards of measurements; The search for oil; Animal behavior; The national wildlife refuge program of the Fish and Wildlife Service; A living fossil; Insects and the spread of plant diseases; The Mexican bean beetle; Plant-tissue cultures; Prehistoric culture waves from Asia to America; Masked medicine societies of the Iroquois; The beginnings of civilization in eastern Asia; Stonehenge—Today and yesterday; The botany and history of *Zizania aquarica* L. (wild rice).

OBSERVATIONS ON PLANTS AND INSECTS IN NORTHWESTERN BAJA CALIFORNIA, MEXICO, WITH DESCRIPTIONS OF NEW BEES. *Transactions of the San Diego Society of Natural History, Vol. 9, No. 31.*

By T. D. A. Cockerell. Society of Natural History, San Diego, Calif. 10⅛ x 6¾; 12; 1941 (paper).

HUMAN BIOLOGY

THE DOCTORS MAYO.

By Helen Clapesattle. University of Minnesota Press, Minneapolis. $3.75. 9 x 6; xiv + 822; 1941.

This voluminous record of the lives and works of the sturdy Doctor W. W. Mayo and his two brilliant sons, Doctors William J. and Charles H. Mayo, in a frontier community is an important contribution to contemporary American history. From both professional and sociological standpoints, William J. and Charles H. Mayo were men of epiphenominal characteristics who exerted a profound influence upon their times.

Entering into general practice with their father in a small western town, after such inadequate laboratory and clinical training as even the better medical schools in the eighteen-eighties afforded, before the importance of antisepsis was generally recognized and modern asepsis was even conceived of, they soon became absorbed in general surgery. This embraced the application of mechanical measures to the relief and cure of affections of any and all of the accessible organs of the body, including eye, ear, nose, and throat.

As their practice expanded in volume and variety and their means allowed, taking turns, they attended first the clinics of leading surgeons of Chicago, New York, Philadelphia, Baltimore, Boston, and later of Europe. Thus, garnering knowledge in the methods of diagnosis and treatment from many sources to add to the lessons drawn from their own experience, they were the pupils of no one master. Early in their career they attended meetings of medical societies, where, with becoming modesty, they presented their results, often to the astonishment of their colleagues. Combining a judicious blend of boldness in attack and brilliancy in execution with that uncanny appreciation of each patient's actual physical and psychological state which ever distinguishes the great physician or surgeon, they advanced rapidly to a position perhaps unique among the world's greatest practical surgeons.

The hosts of patients from near and far furnished an experience from which in many fields of surgery they were warranted in speaking with an authority well nigh *ex cathedra.*

Lack of space forbids the tracing of the importance of the Mayo connection with the Mercy Hospital under the capable direction of the Sisters of St. Francis, who supplied Sister Josephine as first assistant to the surgeons at operations, as well as efficient nursing service; the expansion of the hospital to meet the rapidly growing clientele; the gradual addition of talented colleagues to the Mayo partnership, with the establishment of one laboratory and clinical section after another; and finally the development of the great Mayo Clinic and the transfer of its rich holdings during the lifetime of the two brothers to a permanent Trust, the income of which, under the supervision of the State University, is devoted to the advanced training of physicians and surgeons.

Throughout the book, perhaps as its most interesting feature, runs as the *leitmotif* the picture of the mutual love and devotion of the two brothers Mayo ("by my brother and I"), of equal but diverse talents, earnest, honest, direct, generous, and simple in their lives and dealings, who so completely complemented and supplemented each other and whose heads were never turned by the adulation of patients or by the honors accorded them by the profession and institutions.

The book, which is abundantly illustrated with photographs, is prolix in places and, to the general reader, overburdened with local color.

MAYA INDIANS OF YUCATAN.

By Morris Steggerda. Carnegie Institution of Washington, Publication 531, Washington, D. C. $2.00 (cloth); $1.50 (paper). 9⅞ x 6½; xx + 280 + 35 figures + 32 plates; 1941.

In this volume Steggerda has brought together much interesting material on the present day Maya Indians. The highly organized society which we know once existed in Yucatan Steggerda believes occurred "when

small migrations of men with new ideas inspired them to build a glorious empire. These men were able to exert their influence only for a limited time, after which their descendants became absorbed into the general population. . . ." The material is organized under the following headings: Piste [where the work was largely done]—past and present; Personality traits and everyday activities; Maise production and animal husbandry; Physical and physiological features; Demography and family history studies.

The outstanding personal characteristics of the modern Maya Steggerda finds to be calmness and cleanliness. Farming provides practically their only means of support. While their ancestors were well advanced in mathematics, astronomy, and architecture the modern Maya have "only numerous strange beliefs, and superstitions concerning the celestial bodies, the winds, the trees, and the ancient ruins."

Numerous records on the physical characteristics, including physical anthropometry of children are given; also the demography of several Indian towns. One of the striking features of the Maya is their excellent teeth—this in spite of the fact that their diet is 80–85 per cent pure carbohydrate and that there is almost no mouth prophylaxis. Another characteristic is the high metabolism, which the author finds must in large part be considered "indication of a real racial effect." The Maya resemble the Chinese in an important, environmentally unaffected character, namely, the configurations of the ridges on the palm." Growth rhythms of the Maya are identical with those of three other races (white, Negro, and Navajo children) selected for comparison. The Maya children and adults are shorter in all ages than are those of the other three races. There are striking physiological similarities in the growth patterns of all four races, in spite of an entirely dissimilar body build and widely different food habits and climatic surroundings. For 605 Maya on whom both birth and death records were obtained, 68.76 per cent died before they were five years old, and 7.93 per cent died between the ages of five and fifteen.

Many graphs and tables and 32 plates are included in this volume, but by far the larger part of the records is in six appendices which are on file at the Division of Historical Research of the Institute.

MARRIED LIFE IN AN AFRICAN TRIBE.

By I. Schapera. With an Introduction by Bronislaw Malinowski. Sheridan House, New York. $3.50. 9¼ x 6½; xvii + 357; 1941.

A description of the family life of the Kgatala, a southern Bantu people now living in Bechuanaland, and its evolution during the last century forms the substance of this excellent work. Before contact with the whites (Dutch first and then the English) the Kgatala family constituted the primary unit of domestic living, and in it were centered the major cultural activities of the tribe. It was the nucleus of the legal, administrative, religious, educational, and economic systems of the tribe, and of course, the mainstay of the sex ethics of the group. With the advent of the laws and religion of the whites, the chief lost his authority, polygamy was abolished and the initiation rites and marriage mores were altered. Furthermore, the men of the tribe were given the opportunity, and were also forced by economic necessity, to obtain wage-paying work away from the village; at the same time the women were enabled to acquire paying skills and training outside the home and the agricultural compound. The effects of such transformations of customs on a population to whom reproduction is the most important obligation can easily be perceived and is revealed in this book with verve, uncommon frankness, and in some detail. Pre-marital and extra-marital sexual unions are now openly tolerated, parental authority has declined considerably, and the family organization has lost its stability. Thus, one sees the usual consequences of the contacts between conflicting civilizations, contacts which produce at least a transitory period in which the system of ethics, the family and social organizations of both civilizations, break down.

The author, preoccupied by the present status of the group he has surveyed, is apparently not aware of the general significance of the phenomenon observed, nor is Malinowski who, in his very laudatory introduction to this work, somehow wishes to tie in the political philosophy of Russia and Germany with the disintegration of the family. Malinowski fails to recall that the demographers of Sweden today present a picture of family life in that country almost identical with that described by the author for the Kgatala.

The author has written this book for the general reader and certainly has succeeded in making it enjoyable as well as instructive. Most of all, Schapera demonstrates a warm sympathy and a remarkable insight into the way of living of the Kgatala whom he has apparently come to know and to thoroughly understand.

SMOKE FROM THEIR FIRES. *The Life of a Kwakiutl Chief.*

By Clellan S. Ford. Yale University Press, New Haven; Oxford University Press, London. $3.00. 9 x 6; xiii + 248; 1941.

The Kwakiutl once formed a powerful Indian nation, living on Vancouver Island. This is the life story of one of their chiefs, seventy-year-old Charley. The author has recorded Charley's own narrative and through skilful, patient questioning has assembled an unusually comprehensive picture of native customs, as they existed on this island before white contact had altered or eradicated them. The games of the young

children helped to equip them for the life which their culture demanded of them as adults.

. . . the old men would say to go and get long spruce twigs, and then we go to war with these. Hardly anybody could stand this game. We would whip each other Anybody who could stand against that was brave. They cut right into your skin, and all of us was bleeding.

When I was quite a big boy, a chief of our tribe called all the chiefs of the Fort Ruperts and told them he was going to give a *tsitsika*. The winter ceremonial is called *tsitsika*, which means "everything is not real." At the Kweka chief's house [during this *tsitsika*], I did my dance—the Warrior dance. I had spruce twigs thrust through the flesh on my thighs by one of the men. He first put a sharp iron through. Then when they took the iron out he put the twig through and put a knot in the twig to hold it together, and the same way in two places on my back. That hurted a little bit, and then they tied a rope onto the twigs and tied it onto the frame of a double-headed snake mask. And they have three poles and lift me up by lifting the mask, and the ropes lifted me and take me along the beach toward the Kweka chief's house. . . . When I am lowered down, they take off the frame and the rope is holded by several men, and they begin to pull while I am dancing while they sing my song. . . . And then they begin to pull the ropes and try to break the twigs out of my leg and back. . . . When they couldn't break my skin, they took my knife away from me and cut my skin, . . . Hanging around tied with white thread and a needle stuck in me all over, holding each one of these little paddles, holding a double-headed snake made out of yellow cedar wood in my hands all carved and I come out and dance. That's all I have on when I dance that night. Hemlock branches is around my head.

The old man's frank and detailed account of his life forms interesting reading and represents a very valuable ethnographic document. There is no index.

SOUTHWESTERN ARCHAEOLOGY.
By John C. McGregor. John Wiley and Sons, New York: Chapman and Hall, London. $5.00. 10 x 6½; x + 403; 1941.

The science of archaeology is as yet too young to be very well systematized. The archaeologists are too busy assembling new material to cooperate in the integration of what is already known. This is as it should be, for no science suffers so much from the advances of so-called civilization as this, with the wholesale destruction of archaeological material when virgin cover is ploughed for cultivation or when ancient ruins are raided to supply modern building material. And what price would be too great to pay for some of the documents destroyed wilfully in the conflgrations of Alexandria and Tenochtitlan!

But the time when archaeology shall be integrated into a systematic science is no longer remote. The present work seeks to accomplish that task for that portion of the United States where archaeological remains are the most numerous. Not only was the population density in the southwest higher than elsewhere on the continent in prehistoric times, but exactly the opposite condition obtains today, so that the artifacts of early cultures have been but little disturbed.

The book begins with a description of the geology, physiography, and climatic conditions of the area, then follows a discussion of the historic record, the method of dating ruins by dendrochronology, a discussion of the different routes by which man came to the Western Hemisphere, and a discussion of the sources of information. All of this is purely introductory material. Then follows the main portion of the book—a description of the arrow points, pottery, and refuse and burial mounds that have been dated, together with numerous excellent photographs of many of them. These are presented not as so many isolated facts, but are tied into each other so that they constitute a related whole.

At the end of the book are several appendices containing lists of archaeological sites, dates of different types of pottery, etc., and a glossary of technical terms, with detailed bibliography and an extensive index.

We need more archaeological works of this sort.

THE HAWAIIAN PLANTER. *Volume I. His Plants, Methods and Areas of Cultivation. Bernice P. Bishop Museum Bulletin 161, 1940.*
By E. S. Craighill Handy. The Bernice P. Bishop Museum, Honolulu. $2.50. 10 x 6¾; iii + 227 + 8 plates; 1940 (paper).

The author holds the opinion that subsistence agriculture of native peoples should become the object of study by ethnologists. This aspect of material culture is of prime importance and is also less changeable than many of the arts and crafts which have mainly occupied the attention of ethnologists in the past. The volume deals with the cultivated plants and the agricultural technics of the Hawaiian before he came in contact with Westerners. One of the difficult phases of this work has been the translation of the rich Hawaiian vocabulary dealing with plants and their various parts into scientifically accurate English.

More than half of the book is devoted to the study of taro: the methods of planting both wet and dry taro, its uses, and the planting districts on the various islands. In Hawaii, where hundreds of varieties of such cultivated plants as taro exist, the ethnologist faces the problem of the complicated taxonomy of the subsistence crops with which he is concerned. The author has endeavored to meet this in his extensive research in the field. Very detailed lists of Hawaiian names for varieties, especially of taro and sweet potatoes, are given. How far this material can be successfully applied in further studies is difficult to judge. At least the book brings out interesting points regarding the multitude of uses to which a single plant has been put and the remarkably large number of varieties which

have been developed for use in restricted localities with differing soil and climatic conditions.

Sweet potatoes, yams, bananas, sugar cane, breadfruit, coconut and a number of less-known Hawaiian food plants account for the rest of the book. It is well illustrated with drawings intended to help students to identify varieties of the main early food plants of Hawaii, with maps showing planting localities, and with photos of plants and fields under cultivation.

This book will especially interest the student of anthropology and all those concerned with elements of material culture of the early Hawaiians and of Polynesians in general.

THE SOCIAL LIFE OF PRIMITIVE MAN.

By Sylvester A. Sieber and Franz H. Mueller. B. Herder Book Company, St. Louis and London. $3.50. 8 x 5⅝; xiii + 566; 1941.

This volume epitomizes, with some revisions, the well-known *Volker und Kulturen* by Schmidt and Koppers. It outlines the fundamental concepts of the Culture Historical School of Ethnology, a school of thought that holds views which are in many respects sharply in contrast with the prevailing opinion of the majority of ethnologists of this country, at least. The culture historical method seeks to determine the sequence of prehistoric cultures by assuming that this order can be ascertained from the study of existing peoples of various degrees of civilization. That is, the more primitive cultures of the present day represent the survival of more or less universal civilizations that have disappeared. According to this school, three main culture groups preceded the historic civilization. The first in order of antiquity is called "primitive" and is exemplified by the Pygmies, among others. The second, called "primary," is further subdivided into (a) the exogamous totemist culture of higher hunting (Kwakiutl), (b) the exogamous matrilineal culture of horticulturists (Iroquois), (c) the exogamous patriarchal culture of pastoral nomads (Lapps). The third group, termed "secondary," is subdivided into (a) the free matriarchal culture (Battack of Lumatra), (b) the mother right and totemist culture (Dravidics), and finally (c) the free patriarchal culture from which our historic civilization is descended.

The socio-economic characteristics and the presumed development of each of these culture groups are described briefly. Among the main controversial points which derive from this view one concerns the development of the bilateral family which Schmidt believes was present in the primitive cultures, and another is the religious significance of totemism which, according to Schmidt, is over-rated. There are obviously criticisms of a logical as well as a factual nature to be leveled at the method and results. However, it must be admitted that to some degree Schmidt has achieved a broader synthesis of the subject than has so far been possible heretofore.

CRIMINOLOGY. *A Scientific Study of the Modern Crime Problem.*

By Eligius Weir. Introduction by Father Flanagan. Institute for the Scientific Study of Crime, Joliet, Illinois. $3.00. 9 x 6; xx + 329; 1941.

Father Weir has for a number of years been chaplain in the Illinois Penitentiaries of Joliet and Stateville, and at the same time is Professor of Criminology at the College of St. Francis. The combination of these several attributes has led to the viewpoint which emphasizes the responsibility of society with regard to both the prevention of crime and the reformation of the criminal. In this volume which is proposed as a textbook he presents a comprehensive survey of (1) the criminal laws of this country, (2) crime detection and law enforcement agencies, (3) the functions of the legal profession, (4) prison systems and punishment of crime. His discussion of these topics is highly critical. He points out the inconsistencies of the laws in relation to the punishment of crimes, the official complacency towards misdeeds by the legal profession and the flaws in the practical management of the problems of imprisonment and of probation. In brief, he puts his finger on the very weaknesses which from time to time are glimpsed but never wholly perceived by the general public. He cites case after case to bring home his points, and if names and places had been included either the author would himself be placed in prison or else the public would be aroused to violence. Father Weir offers many constructive suggestions to remedy the evils. Among these are the standardization of criminal laws throughout the country, the removal of politics from the judiciary, the centralization of law enforcement agencies, the recognition of the relation between crime and physical and mental disorders, the development of more adequate methods of meting punishment to take into account the personality of the criminal and the possibility of his reeducation. The author believes also that crime can be prevented through the efforts of the church, the home, and the school. This is a well-written book and one to interest all citizens in all professions.

FAMILY EXPENDITURES FOR CLOTHING. *Five Regions. U. S. Department of Agriculture Miscellaneous Publication No. 428. Consumer Purchases Study. Farm Series.*

By Day Monroe, Maryland Y. Pennell, Elizabeth Phelps, June C. Hopper, and Helen Hollingsworth. Government Printing Office, Washington, D. C. 30 cents. 9⅛ x 5¾; iv + 387; 1941 (paper).

FAMILY EXPENDITURES FOR FURNISHINGS AND EQUIPMENT: *Five Regions. U. S. Department of Agriculture Miscellaneous Publication No. 436. Consumer Purchases Study. Urban, Village and Farm Series.*

By Day Monroe, Helen Hollingsworth, Margaret Perry, and Maryland Y. Pennell. Government Printing Office, Washington, D. C. 25 cents. 9⅛ x 5¾; iv + 212; 1941 (paper).

The first of these reports, on ways of spending for clothing, is a study of

non-relief, unbroken, native-white families of farm operators in 13 farming sections representing the major types of agricultural production in this country. Farm laborers and paid managers were excluded except in the Southeast where a special study was made of the tenure-labor group, sharecroppers. Data for Negro families, both operators and sharecroppers, were also obtained in the Southeast region and are presented separately.

Groups of counties in the general farming section of Pennsylvania and Ohio were selected for special text presentation, and more detailed discussions on the use of clothing funds by each of 11 groups of family members are furnished for a large analysis unit that combines all the farm communities surveyed in the North and West.

The second report dealing with expenditures for household furnishings and equipment is based on surveys made on families living in 13 farm sections, 140 villages, and 20 small cities—data for Negro families, for the Southeast region only, being presented separately.

As in all previous reports on the Consumer Purchase Study (conducted under the auspices of the Works Projects Administration) statistical tables form a large part of the surveys.

ABOUT OURSELVES. *A Survey of Human Nature from the Zoological Viewpoint.*

By James G. Needham. The Jaques Cattell Press, Lancaster, Penna. $3.00. 10 x 6¾; xi + 276; 1941.

Popular books on man from the point of view of naturalists are always needed, lest man forget that he is merely one of nature's endless experiments and as such is governed by inescapable biological laws which can explain (and excuse) his makeup and behavior with all its imperfections and compromises. Professor Needham has produced an outstanding volume of this sort by writing in an attractive, clear style, by presenting well-chosen chapters without unessential detail, and by consistently avoiding proposals and propaganda for improving mankind. The author's blunt and self-assured philosophy permeates his writing in a fashion stimulating to the layman and challenging to the specialist. He never hesitates to explain the most puzzling problems in often original, though at times all-too simplified, a manner. At various places his arguments carry the discussion far from the proper domain of biology and appear somewhat naive.

The first 71 pages furnish a biological background with condensed surveys of the animal kingdom, the order of primates, fossil men, and the development of the brain. The subsequent 200 pages deal chiefly with some biological aspects of really psychological and sociological subjects and include such topics as religion, folkways, government, and war. Concerning war, the most timely of these varied items, it is stated that "ours is a fighting species." In such species the males are larger than the females, they are better armed, more gaudily decorated, more highly endowed vocally, and are willing to defend the family. One wonders whether even lay-readers can be convinced by these and many similar, sweeping generalizations.

DEEP SOUTH. *A Social Anthropological Study of Caste and Class.*

By Allison Davis, Burleigh B. Gardner and Mary R. Gardner. The University of Chicago Press, Chicago. $4.50. 7⅛ x 5⅜; xv + 558; 1941.

Following the pattern already set by a number of investigators, the authors, assisted by other field workers, lived for two years in a southern town, "Old City," and there participated in the social life of the community to study the socio-economic stratifications of the whites and of the Negroes, and the interactions between the two color groups. Their observations are reported in detail and in summary indicate that the inhabitants of the community

live in a social world clearly divided into two ranks, the white caste and the Negro caste. These color-castes share disproportionately in the privileges and obligations of labor, school and government, and participate in separate families, associations, cliques, and churches. Only in the economic sphere do the caste sanctions relax, and then but for a few persons and in limited relationships. Within the castes are social classes, not so rigidly defined as the castes, but serving to organize individuals and groups upon the basis of 'higher' and 'lower' status, and thus to restrict intimate social access.

Such findings would have been expected, but, although the wealth of information acquired has importance, one is struck by the superficiality of this kind of survey. There is obvious need for precise data on social behavior in our civilization but it seems that, since already a certain fund of knowledge is at hand, students of the subject could and should attempt to probe deeper into the matter. However, this excellent piece of accurate reporting is not to be dismissed as inconsequential since it again brings to the fore one of the most important problems that faces the country, to wit, the problem of stabilizing the relationship between the whites and Negroes.

BECOMING A KWOMA. *Teaching and Learning in a New Guinea Tribe.*

By John J. W. Whiting. With a Foreword by John Dollard. Yale University Press. $2.75. 9 x 6; xix + 226; 1941.

Anthropology has barely begun to study intensively the problems concerned with the transmission of culture or group habits from one human generation to the next. Such study must deal with child training, the processes of teaching and learning, as influenced by reward and punishment, and the causes of the origin or disappearance of cultural traits. The ultimate and generally valid conclusions from research of this nature will have to rest upon many comparative observations, gathered laboriously among widely differing tribes and cultural levels.

The present scholarly, yet very readable contribution, is the result of field work in a primitive, homogeneous, and economically non-specialized tribe (Kwoma) from the interior of New Guinea, north of the Sepik river. The first part is largely descriptive, picturing the varied aspects of Kwoma culture, particularly as they affect the daily life of children from infancy to adulthood. The second part deals extensively with theories of learning and of socialization in a careful attempt to analyze the behavior of these Kwoma children in the course of their development. In this, the author leans heavily upon Freudian hypotheses, paying much and quite uncensored attention to the rôle of sex.

From some passages in the book it appears that these naked savages can teach their offspring to behave properly with more ease, grace, and effect than is at the command of many a civilized parent.

There is a useful index, but there are only a few and mediocre illustrations.

YALE UNIVERSITY PUBLICATIONS IN ANTHROPOLOGY. *Numbers 23 and 24. Excavations in the Ft. Liberté Region, Haiti,* by Froelich G. Rainey; *Culture of the Ft. Liberté Region, Haiti,* by Irving Rouse.

Yale University Press, New Haven; Oxford University Press, London. Nos. 23 and 24 bound under one cover, and sold only as a unit, $3.50. 9¾ x 7; No. 23, 48; No. 24, 181 + 35 plates; 1941 (paper).

The first half of this study is largely a description of the field work relating to the archeological investigations conducted by the Yale Peabody Museum in the Ft. Liberté Bay region of northern Haiti in the summers of 1934–35. In all, eleven different sites in this region were excavated with the help of native guides and workers. The discussions include detailed descriptions of the methods of locating worthwhile sites, the geological stratification of each, and the skeletal finds.

The second part of the study is concerned with a description and classification of the cultural artifacts collected during the investigation. Included in this report also are discussions relating to the probable modes of subsistence, social organization, language, religion, burial, trade, and warfare of the now extinct native Indian population of Haiti. From the data at hand, it is evident that the native Indians of Haiti were similar in many respects to their contemporaries in Central and South America, and had reached a fairly high point in their neolithic culture.

Both reports are well documented, and present an abundance of tabular and illustrative material in support of the discussions. Each carries a table of contents.

AN APACHE LIFE-WAY: *The Economic, Social, and Religious Institutions of the Chiricahua Indians.*

By Morris Edward Opler. The University of Chicago Press, Chicago. $5.00. 8 x 5½; xvii + 500; 1941.

The exposition of the subject particularly distinguishes this ethnographic description of the Chiricahua Apache. The author seeks to portray in order the sequence of social reactions manifest by these Indians from birth to death. One by one he introduces the societal elements: family, culture, economy, religion, etc. which affect the life of the individual and mold him into an Apache. This approach is very effective and is rendered even more interesting by the abundant use of direct quotations from the Indian informants. Hence, the present work acquires almost the characteristics of an autobiography of a composite Chiricahua, and the personality of the author seemingly intrudes very little. By such a method the rationale of the individual or group reactions is clearly brought out and is not the product of the inferences of the observer from another civilization. By the same token one also runs the risk that the informant will seek to justify the actions of his group in terms of the observer's social values. Thus, in the text one notes that the informants emphasize continuously the peacefulness, morality, and other Christian virtues of the Chiricahua. If these are flaws they are the only ones to be noted in this thorough and authoritative account of the life and mores of the Apache group studied.

DIE VIERLINGSGESCHWISTER GEHRI UND IHR VERWANDTSCHAFTSKREIS. *Eine familienanthropologische Untersuchung. Archiv der Julius Klaus-Stiftung, Band 15, Heft ¾.*

By Otto Schlaginhaufen. Art. Institut Orell Füssli A.-G., Zürich. 9½ x 6¾; 309–398 + 10 genealogical tables + 7 plates. 1940 (paper).

The subjects of this study—Oskar, Bertha, Rosa and Arthur Gehri—were born as four-ovum quadruplets in Switzerland in 1880 and were still living and in good

health at the time this monograph was written. The most complete anthropometric data were obtained by the author when they were 45½ years of age. Data on the earlier years of their life were obtained from various sources, including hear-say information and studies of photographs. In infancy and early childhood they looked alike and their personalities were similar. Differences became more apparent as they grew older but even in middle age they were more similar to each other than to any of their 3 single sibs and 3 half-sibs, and also more similar than were any other individuals of their sibship to each other. The author ventures the hypothesis that environment may here have played a rôle, as their environment in successive years was more similar at a given age than that of the other sibs born several years apart. Pedigrees of the maternal and paternal direct and collateral lines for five generations were also studied. The families of both parents showed a history of twinning. That of the mother had 7 pairs of twins in the paternal and 5 pairs in the maternal lines. The father's mother was a twin and one of his nieces bore a twin. The pedigree charts are appended and there is a bibliography.

KÖRPERLICHE ENTWICKLUNG NACH FORM UND LEISTUNG BEI MITTELSCHÜLERN VON AARAU.

By Eugen Morf. Manatschal Ebner and Cie, Zurich. 9½ x 6¾; 231 + 29 tables; 1939 (paper).

The greater portion of this book is devoted to the absolute and relative figures found in a large series of anthropological measurements made on 477 boys and 170 girls between the ages of 16 and 20 in Aarau, Switzerland. In addition to body measurements, measure of pulling capacity, hand grip strength, running high jump and running broad jump, exercises on horizontal bars, climbing, and weight pulling are included. It was noted that growth continued in practically all height and breadth components in both girls and boys from the ages of 16 and 19 years. The exceptions were ilio-spinal height, tibial height, and hand breadth and length. Growth was more evident in boys than in girls beyond the age of 16. In the same sample studied, groups from the upper social classes tended to be both taller and heavier than the boys and girls from the lower income brackets. An appendix tabulates the statistical means, coefficients, and ranges for each measurement made, grouped by age and sex. There is a bibliography.

WESTERN AND SOUTHWESTERN INDIAN SKULLS. *University of Denver Anthropological Series, First Paper, 1941.*

By E. B. Renaud. University of Denver, Denver. 85 cents. 8¾ x 11; 94; 1941 (paper).

During the past fifteen years Renaud has published in various places records on Indian skulls from the Western Plains and Southwest. He has now brought this material, as well as hitherto unpublished data, together under one cover in order to make it more readily accessible. The material is grouped as follows: Western crania or Plains Indians skulls (Nebraska and Colorado skulls); Southwestern crania (Pueblo, Basket Maker, and Mound Builder skulls); and a Palae-American type (comparative study of prehistoric skulls).

The numerous tables of measurements and indices of crania studied which form part of the report are a useful contribution to the literature of physical anthropology of the American Indian. The study concludes with a bibliography of 45 titles.

ZOOLOGY

GUIDE TO THE FISHES OF THE GREAT LAKES AND TRIBUTARY WATERS. *Cranbrook Institute of Science Bulletin No. 18, August, 1941.*

By Carl L. Hubbs and Karl F. Lagler. The Cranbrook Press, Bloomfield Hills, Mich. $1.00 (cloth); 50 cents (paper); 9 x 6; [100] + 16 plates; 1941.

The systematic and geographic relationships of some of the forms of the fish fauna of the present Great Lakes and its tributaries "have been rendered very complex by the continental glaciers which covered the region during the Ice Age, as well as by evolution." In the glacial era the large bodies of water which formed in front of the great ice cap overflowed southward to the Gulf through the rivers of the Mississippi valley, and to the Atlantic Slope through the Susquehanna, Mohawk, Hudson, and St. Lawrence valleys. With the retreat of the ice sheet the lakes became smaller and drainage from the southern region of the Great Lakes Basin much restricted. The waters from the Finger Lakes region and from central New York, however, turned into the Lake Ontario basin. In modern times canals have restored the connections of the Great Lakes waters with those of the great rivers to the south, and the barrier of Niagara has been broken down by the Welland and Trent canals. In addition to the early fish fauna of the Great Lakes Basin and the forms which have entered more recently through the artificial connections, the smelt, landlocked salmon, brown trout, rainbow trout, carp, and gold fish have been introduced by stocking.

The present guide lists 229 kinds of fishes, native and introduced, "which are now known to live in the Great Lakes and their tributaries, or to have occurred there in historic times, . . ." Detailed directions for counting scales, fin rays, etc., and for measuring body lengths and other dimensions are given as a basis for learning

the salient characters of fishes. The keys are well planned and, in a group of plates, figures of 118 forms are shown. The geographic range—an excellent map is provided—of species and subspecies has been worked out not only from published material but from a great amount of original data. Much of the original information is based on specimens and records in the University of Michigan Museum of Zoology. The work concludes with a reference list of eight pages and an excellent working index. A guide which will be found extremely useful by the amateur as well as by the professional zoologist.

A MONOGRAPH OF THE EXISTING CRINOIDS. *Volume I. The Comatulids. Part 4a. Superfamily Mariametrida (excepting the family Colobometridae). Smithsonian Institution, U. S. National Museum Bulletin 82.*

By Austin H. Clark. U. S. Government Printing Office, Washington. $1.50. 12¼ x 9¾; 603 + 61 plates; 1941 (paper).

Several monographs have already been issued from the U. S. National Museum on the crinoids. Parts 3, 4, and 5 of Volume I, Bulletin 82, include the systematic discussion of the species and higher groups of living comatulids, or unstalked crinoids. Part 3 (cf. Q. R. B., Vol. 7, p. 114), published in 1931, includes the superfamily Comasteridae. The present volume, a continuation of Part 3, includes the account of the second of the three superfamilies of the Oligophreata, with the exception of the Colobometridae. The volume represents an enormous amount of detailed, careful, taxonomic work upon a difficult group. It is illustrated with a group of fine plates (283 figures).

Since the publication of previous work dealing with the structure and morphology of the comatulids was published much additional work has been done by others. Some of these authors have differed with Clark on interpretation of structural peculiarities. In the first 73 pages of the present volume Clark presents a summary of their work. He fails to find, upon a careful analysis, any reasons for altering his opinions already expressed.

The main point of divergence between my opinions and those of my colleagues hinges upon the weight to be given the Paleozoic and earlier Mesozoic forms in an elucidation of the structure of recent types. I maintain that until the recent crinoids are far better known than they are at present, especially in regard to their younger stages, it is futile to attempt to interpret the details of their structure from comparison with earlier forms. For most of the earlier forms, as we know them, represent the terminal twigs of developmental branches of which the generalized beginnings are unknown, just as the adults of the recent forms represent the ultimate product of an unknown ontogeny. And even if the earlier stages of all the recent forms were known, it is by no means certain that these would give any definite clue to their ancestry and morphological relationships when compared with the adults of earlier types. Until we are in possession of sufficient facts to enable us to understand the recent types, and thus to be sure of our ground, we are likely to be led astray rather than aided by any detailed comparison with fossil types."

SYSTEMATIC CATALOGUE OF THE FISHES OF TORTUGAS, FLORIDA: *With Observations on Color, Habits, and Local Distribution. Papers from Tortugas Laboratory, Volume XXXIV. Carnegie Institution of Washington Publication 535.*

By William H. Longley. Edited and Completed by Samuel F. Hildebrand. Carnegie Institution of Washington, D. C. $3.50 (cloth); $2.50 (paper). 10 x 6⅝; xiii + 331 + 34 plates; 1941.

The late Dr. Longley was a pioneer in using the diving helmet for the study of fishes in their natural environment. He found that many fishes are not afraid of the diver. Thus he was able to approach them and make his observations on behavior, feeding habits, and adaptive coloration at close range. An under-sea camera and a wax-covered slate for taking notes, which were later transcribed to paper, were part of his equipment. Longley was unable to complete the present monograph but at his request, Hildebrand, senior ichthyologist of the U. S. Fish and Wildlife Service, has performed this task. Organizing and bringing to fruition the work of another is always a difficult undertaking, requiring laborious research for a comprehension of the author's notes and records. Hildebrand has done this with skill and understanding. In the Introduction he says:

Without doubt, Dr. Longley, after a quarter of a century of diving at Tortugas and elsewhere, knew the habits and haunts of tropical and subtropical reef fishes better than any other person of his day." . . . the most important part of this monograph consists in the under-water observations reported. These observations are the more important because of Dr. Longley's accurate knowledge of species. It is evident from the great amount of time he spent in museums . . . during the later years of his life in the study of types and other important specimens that he was more and more impressed, as his work progressed, with the supreme importance of the proper recognition of species.

Among the 34 plates at the end of the volume will be found many interesting photographic reproductions showing various forms of fishes in their natural habitat. A complete index of the forms described is provided. Both the systematist and the student of the biology of fishes will find this a valuable reference work.

MOSQUITOES OF THE ETHIOPIAN REGION. *III. Culicine Adults and Pupae.*

By F. W. Edwards. The British Museum (Natural History), and Oxford University Press, London. 16s. 10 x 7; viii + 499 + 4 plates. 1941.

Two parts of this valuable reference work have been previously issued. Part I—*Larval Bionomics of Mosquitoes and Taxonomy of Culicine Larvae*, by G. H. E. Hopkins was issued in 1936 (cf. Q. R. B., Vol. 12, p. 109); Part II—*Anophelini: Adults and Early Stages*, by A. M. Evans, in 1938 (cf. Q. R. B., Vol. 14, p. 245). The present volume completes the Monograph. The author's death occurred as the material was about to go to press.

The number of known species of Culicine mosquitoes of the Ethiopian region has advanced from about 180 in 1927 to about 290 now described, besides some 40 named subspecies and varieties. This increase "is in part due to the rectification of errors through which forms which are now considered distinct species had been lumped together, but still more to the discovery of numerous forms which until recently were entirely unknown." Although the author had a vast amount of material at hand "much further collecting is needed before the African fauna can be catalogued upon a basis that is secure both as to specific limits and generic conceptions." The information herein given is sufficient, however, to identify all but a few of the African mosquitoes with certainty. Included in the description of each species is information on distribution, so far as now known—but this data, it is stated, is often far from complete.

In Section IV.—Zoogeography of Ethiopian Mosquitoes, the following topics are discussed: (1) Comparison with mosquito faunas of adjacent regions; (2) Faunal divisions of Africa as exemplified by mosquitoes; (3) Ecological classification; (4) Present distribution in relation to the past; (5) Sources and extent of our present knowledge; (6) List of Ethiopian mosquitoes with summarized distribution. Numerous illustrations are given in the text, a list of references is provided also an index to the names of mosquitoes.

TOTO AND I: *A Gorilla in the Family.*

By A. Maria Hoyt. Introduction by Roger Conant. J. B. Lippincott Company, Philadelphia and New York. $2.50. 8⅜ x 5⅞; xxiv + 238; 1941.

This is a popular account of the daily happenings in the life of that much publicized anthropoid debutante "Toto," now the bride of the famous gorilla "Gargantua." The late Mr. Hoyt shot Toto's father in French Equatorial Africa and Mrs. Hoyt adopted the helpless infant, for which a native wet-nurse had to be found. Toto lived in a luxurious home under devoted care for nine years when her 438 pounds became too large a problem and she had to start a public career in a circus. This happened after she had carried a Japanese servant up into a tree.

In view of the sudden and unpredictable changes in the temper of adolescent apes one reads with shudders of the freedom Mrs. Hoyt had granted to her house pet and "problem child" long after such indulgence had ceased to be a reasonable risk. In one of the last chapters, entitled "Toto the Comforter," the author admits that:

> Our difficulties were always tremendously increased during two or three days of every month when Toto seemed to fall in love with one of the men. Sometimes it was one of the gardeners, a tall handsome chap, sometimes José, the second chauffeur, sometimes the butler. During these periods, she would follow the object of her affections about the grounds, . . .

The primatologist will welcome the 35 good photographs illustrating the rapid development of a gorilla, but he will be disappointed to find no sound observations of scientific value for which existed such rare opportunities. To judge by her extraordinary weight and by her most recent pictures Toto has developed into the equivalent of a professional Fat Lady and it seems doubtful that her coming wedded life will result in a blessed event. Let us hope this prognosis is wrong and that Toto will soon present Gargantua and what is left of the scientific world with the first captive-born gorilla!

A LOT OF INSECTS. *Entomology in a Suburban Garden. By Frank E. Lutz. G. P. Putnam's Sons, New York.* $3.00. 8¼ x 5½; 304; 1941.

Rarely do we find a book whose title so nearly embodies the essence of the subject matter as is the case of *A Lot of Insects*. Within these pages the author has recorded in a very interesting manner, his experiences of the past several years in observing, collecting, and experimenting with the "six-footed visitors" which have come to his suburban garden. The astounding feature of the work is that on a lot measuring 200 x 75 feet, the author has casually collected and identified no less than 1402 separate species of insects. The collected materials now make up a feature attraction labelled "Insects of a Suburban Yard" in the display room at the American Museum of Natural History.

The subject has been presented in a very unique and unorthodox fashion, following neither taxonomic nor pedagogic principles, but just in the order in which the author remembered the experiences. The text is rich in experimental observations, particularly with respect to the insect's special senses, habits, and sounds. The clarity with which the author has stated his experiences is surpassed only by the frankness with which he admits that there is much yet to be learned about the ways of insects.

The frequent excursions from the purely scientific to the humorous and imaginative phases of entomology make for delightful and stimulating reading. Through-

out the work there is mild plea for a better popular understanding of insects both from the point of view of their charm and interest *per se*, as well as from the aspect of their economic importance. The footnotes are gathered into a 42-page "In Addition" at the end of the volume. The text is supplied with an abundance of excellent illustrative material and an index.

FACTORS AFFECTING THE GENERAL STATUS OF WILD GEESE AND WILD DUCK. *International Wildfowl Inquiry, Volume I. The International Committee for Bird Preservation (British Section).*

By Various Authors. With a Foreword by Percy R. Lowe. Cambridge University Press, Cambridge; The Macmillan Company, New York. $2.25. 9 ⅜ x 6½; x + 123; 1941.

In less than a hundred years there has been a complete revolution in the conditions governing the habits and numbers of wildfowl in many parts of the world. The breech-loading gun, the steam-engine, the motor car, and motor boat, to mention only a few examples, have not only enormously increased destruction, but by disturbance of previously quiet and unmolested breeding grounds in the far north, have led to marked changes in distribution. To obtain both general and specific information concerning this state of affairs, the International Committee for Bird Preservation has adopted a far-reaching program of investigation. This first volume of the Committee's report contains an introduction describing the events leading to the formation of the Wildfowl Inquiry Sub-committee and eight papers by specialists, namely: Conditions in northern breeding areas; The distribution of *Zostera* and other seashore plants in relation to the migration of wildfowl; British decoys; Punt-gunning; Ringing of duck at British decoys; Results of ringing duck; and Close time. Although the report deals with conservation problems in Europe, and the British Isles in particular, American conservationists would do well to acquaint themselves with the information gathered about a problem which is world-wide in scope.

FIELD BOOK OF SNAKES *of the United States and Canada.*

By Karl P. Schmidt and D. Dwight Davis. G. P. Putnam's Sons, New York. $3.50. 6¾ x 4; xiii + 365 + 34 plates; 1941.

Not even fish-stories deviate from the truth as often and as far as do popular beliefs regarding snakes. This splendid little volume is of much-needed help in replacing snakelore with sober herpetological information, authoritative, comprehensive, well arranged, and not overburdened by unessential detail. The first of the many excellent photographs shows a rattlesnake unhesitatingly crossing the horsehair rope with which a camper had thought to safeguard his sleep.

The great variety of subjects considered in the first part includes the history of the study of North American snakes, an anatomical description of the poison apparatus, the treatment of snake bite, the methods of collecting and preserving snakes, and suggestions to amateur students for new and useful observations on snakes.

The largest part of the volume gives a systematic account of all our snakes with as clear and convenient keys for species determination as this complicated matter permits. A great many text figures, showing head formation, scale pattern and geographical distribution, a selected bibliography, and a lengthy index add to the usefulness of this field book.

THE HERPETOLOGY OF HISPANIOLA. *Smithsonian Institution. United States National Museum Bulletin 177.*

By Doris M. Cochran. U. S. Government Printing Office, Washington, D. C. 70 cents. 9¾ x 6; vii + 398 + 12 plates; 1941 (paper).

The natural history of island fauna has for many years provided pertinent material for studies in taxonomy and evolution. While the present study of the herpetology of Hispaniola is concerned largely with taxonomy, it is apparent that the extremely rough topography of the island has been responsible for the isolation and subsequent evolution of many interesting forms.

The author's purpose of "advancing the survey of the amphibian and reptile fauna of the Greater Antilles" has been amply fulfilled in this report. The work, based on many years of painstaking field and museum observations, lists 14 families representing 32 genera and numerous species of amphibians and reptiles native to Hispaniola. The discussion of each species includes a detailed description, a list of measurements, the principal variations, the habitat, the paratype, and the relationships to other species. The work is abundantly supplied with tabular material and illustrations, both graphic and photographic. For most of the amphibians, the illustrations include a dorsal and ventral view of the entire body, a profile of the head, an interior view of the mouth, and a view of the under side of the hand and foot. For the reptiles, the illustrations show the scale pattern for the top of the head, the profile, and the chin. The study is documented with a 5-page bibliography, and carries a comprehensive index.

ZOOLOGICA. *Scientific Contributions of the New York Zoological Society. Volume XXVI, Part 3, Numbers 19–27.*

New York Zoological Society. Zoological Park, New York. $2.00. 10½ x 7; 143 + 28 plates; 1941 (paper).

This number contains the following papers:

Eastern Pacific Expeditions of the New York Zoological Society. XXVI. Crabs of the Genus *Uca* from the West Coast of Central America, by Jocelyn Crane (9 plates, 8 text-figures); Eastern Pacific Expeditions of the New York Zoological Society. XXVII. A Study of Young Sailfish (Istiophorus), by William Beebe (5 plates, 9 text-figures); On the Reproduction of *Opsanus beta* Goode & Bean, by Charles M. Breder, Jr. (2 plates); On the Reproductive Behavior of the Sponge Blenny, *Paraclinus marmoratus* (Steindachner), by Charles M. Breder, Jr. (3 plates, 1 text-figure); The Chromatophores of *Fundulus heteroclitus* in Polarized Light, by A. M. Shanes and Ross F. Nigrelli (3 plates); New Races of Alaudidae and Timaliidae from Northern Thailand, by H. G. Deignan; Respiratory Behavior in Fishes not Especially Modified for Breathing Air Under Conditions of Depleted Oxygen, by Charles M. Breder, Jr. (1 plate); Eastern Pacific Expeditions of the New York Zoological Society. XXVIII. Fishes from the Tropical Eastern Pacific. [From Cedros Island, Lower California, South to the Galapagos Islands and Northern Peru.] Pt. 3. Rays, Mantas and Chimaeras, by William Beebe and John Tee-Van (4 plates and 40 text-figures); Erotylidae of Kartabo, Bartica District, British Guiana. (Coleoptera.), by C. H. Curran (1 plate and 1 text-figure).

University of California Publications in Zoology' *Vol. 46, No. 1. The White-Crowned Sparrows (Zonotrichia leucophrys) of the Pacific Seaboard: Environment and Annual Cycle,* by Barbara D. Blanchard.

University of California Press, Berkeley. $2.00. 10¼ x 6¾; 135 + 20 plates; 1941 (paper).

The general plan of this study has been to assemble the most complete picture possible of the year-round behavior and reproductive physiology of two populations of white-crowned sparrows, one migratory, the other resident, of widely separated breeding areas. Great emphasis is laid on the history of the male reproductive system as a slow and exquisitely precise time-keeper for individual, racial, and environmental comparisons. Some attention is given to the relatively minor aspects of behavior which are, so to speak, the superficial aspects or indicators of the more deep-seated, cyclic pattern. The book is of particular interest in that it develops the thesis that an understanding, not of minor structural modifications but of the relationship of the annual cycle to the environment, offers the most promising road to the center of problems of distribution and potential evolutionary change.

From Robin to Junco. *Stories of Birds and What They Do.*

By Mary I. Curtis. Houghton Mifflin Company, Boston. 96 cents. 7¾ x 6; 216; 1941.

When city-bred Ann visited her bird-loving uncle in the country he taught her how to observe birds and told her about the habits, characteristic behavior, and foods of many kinds of birds. The descriptions of their rambles and their conversation about the birds they saw—robins, hummingbirds, cardinals, woodpeckers, cowbirds, crows and many others—are reported in this book for the 8 to 11-year olds. The text is written with authority but in a manner to stimulate the interest of the age group for which it is intended. It is printed in a large, clear type which, together with the illustrations, makes a book which should be attractive to children. The illustrations consist of twelve color photographs by Arthur A. Allen of Cornell University and charming black and white drawings on nearly every page which depict characteristic poses and, in many cases, the animation of the birds. The simple, well-planned index is prefaced with explanations for its use by the inexperienced. The end papers show routes of the migratory birds who make their summer homes in the United States east of the Mississippi. The book is suitable for grade-school and public libraries and the child's own book-shelf.

The Birds of North and Middle America: *A Descriptive Catalog of the Higher Groups, Genera, Species, and Subspecies of Birds Known to Occur in North America, from the Arctic Lands to the Isthmus of Panama, the West Indies and Other Islands of the Caribbean Sea, and the Galapagos Archipelago. Smithsonian Institution, United States National Museum Bulletin 50.*

By Robert Ridgway. Continued by Herbert Friedmann. U. S. Government Printing Office, Washington, D. C. 40 cents. 9¾ x 6; ix + 254. 1941 (paper).

The ninth part of this well-known descriptive catalog of birds contains the Gruiformes with the families Gruidae (cranes), Rallidae (rails, gallinules, and coots), Heliornithidae (sun-grebes), and Eurypygidae (sun-bitterns). Although the size of the present volume has been reduced from its original bulk to permit more immediate publication, none of the essential data has been omitted by Friedmann.

All descriptions are based upon a thorough study of specimens and the literature; nothing has been accepted merely because it was written. The sequence of orders in the volume continues to follow Ridgway's plan, but the arrangement of families, genera, species, and subspecies within each order is patterned to agree with that given in Peters' *Check List of Birds of the World.*

Pelagic Whaling in the Antarctic. ix. The Season 1938–1939. *Hvalrådets Skrifter, Scientific Results of Marine Biological Research, No. 25.*

By Birger Bergersen and Johan T. Ruud. Jacob Dybwad, Oslo. Kr. 3.50. 10¾ x 7; 46 + 2 plates. 1941 (paper).

The statistical data pertinent to the reports of 25 floating factories and 196 catchers that took part in the pelagic whaling of the antarctic during the season of 1938–39 are embodied in this monograph. An abundance of charts and tables are used to indicate the number, size, and sex of the different varieties of whales taken, the amount of oil produced, and the extent of area over which the catchers worked. The data are broken down for the months, and presented in terms of barrels of oil per catcher's day.

An important fact emerging from the data at hand is that of a decrease in the number of large animals taken. This is taken as an indication that the whale stocks of the antarctic are being slowly, but surely depleted.

BIG ZOO.

Described by William Bridges. Photographed by Desider Holisher. The Viking Press, New York. $2.00. 9½ x 6½; 160; 1941.

In this book one of the officials of the New York Zoo relates some of the interesting experiences that have occurred in his career. But the greater part of the work consists of photographs of those things that the general public never sees—chiefly the veterinary hospital.

The book lacks the intimate personal touch of Mrs. Benchley's *Life in a Man-made Jungle*, nor is it as large as that work, which has already become a classic. But the New York Zoo is larger and richer than that at San Diego, and so has a greater variety of animal life on exhibit, and the experiences of its curators are more wide-spread. All told, the authors of this work have succeeded in producing an interesting collection of illustrations, with explanatory text. As it is essentially a narrative, there is no index, nor is there any need for one.

UNDER THE SEA-WIND. *A Naturalist's Picture of Ocean Life.*

By Rachel L. Carson. Illustrations by Howard Frech. Simon and Schuster, New York. $3.00. 8¼ x 6; xix + 316; 1941.

This is a literary interpretation of the animal life of the seashore. While the characters that figure in the story have been imbued with personalities, this has been accomplished with scientific accuracy and is not offensive. The illustrations are well executed and the 41 page glossary very helpful.

UNIVERSITY OF CALIFORNIA PUBLICATIONS IN ZOOLOGY. *Vol. 43, No. 15. A Study of Oxymonas minor Zelif from the Termite Kalotermes minor Hagen*, by Joy Barnes Cross. *Vol. 47, No. 2. A Miocene Sea Lion from Lomita, California*, by Gretchen M. Lyon.

University of California Press, Berkeley and Los Angeles. 25 cents each. 10¼ x 6¾; No. 15, 17 + 2 plates; No. 2, 19 + 5 plates; 1942 (paper).

TRANSACTIONS OF THE SAN DIEGO SOCIETY OF NATURAL HISTORY. *Vol. 9, Nos. 29, 30, 32, and 33. The Long-Nosed Snakes of the Genus Rhinocheilus*, by Laurence M. Klauber. *A New Species of Rattlesnake from Venezuela*, by Laurence M. Klauber. *A Vertebrate Faunal Survey of the Organ Pipe Cactus National Monument, Arizona*, by Laurence M. Huey. *Notes on Some Mexican and Californian Birds, with Descriptions of Six Undescribed Races.*

Society of Natural History, San Diego, Calif. 10½ x 6⅞; No. 29, 39 + 2 plates; No. 30, 3; No. 32, 20; No. 33, 7; Nos. 29 and 30, 1941; Nos. 32 and 33, 1942. (Paper.)

BOTANY

AN INTRODUCTION TO THE STUDY OF ALGAE.

By V. J. Chapman. Cambridge: at the University Press; The Macmillan Company, New York. $3.75. 8½ x 5½; x + 387; 1941.

Although intended as a relatively elementary textbook, suitable for university students, this book has a wider usefulness. The first chapter, in the light of more recent taxonomic treatments of the Algae, recognizes and outlines nine living groups and the fossil Nematophyceae. The discussion of these nine groups, covering their morphology, development, reproduction, life histories, distribution, and relationship, occupies the next seven chapters (238 pages). There are numerous helpful illustrations, some from the standard literature, some from less familiar sources, a few original, with many schematic diagrams of phylogeny, relationships, and life histories. While this portion of the book is largely the usual textbook treatment of the field it contains some valuable additional material from the more recent literature and as a whole forms a useful supplement to the well-known texts of Fritsch, Smith, Tilden and others.

It is the second part of the book, however, which greatly extends its value, for in six general chapters, comprising about 130 pages, Chapman presents material not usually made available to the student in phycological texts. His treatment, in Chapter 9, of the general aspects of reproduction and evolution, implemented with schematic diagrams of life cycles and of phylogenetic sequences, with tables of parallelism in evolution, with definitions of significant terms, and with general summaries, will prove especially useful

to the student. His treatment of fossil forms, although brief, will serve as an introduction helpful to those whose schedule does not permit examination of the extensive literature in English or to those for whom the German of Kräusel, Pia, and Hirmer is a serious obstacle. His treatment, in Chapter 10, of recent physiological work will also prove very useful to the student since it comprises significant material usually omitted from algalogical texts, while his survey of symbiosis, even though brief, cannot help but awaken the interest of the reader, and his discussion of the soil algae renders available to the student important material not usually included in texts, yet of considerable biological and practical interest.

As Chapman is primarily an ecologist and his own work, both that done along the coast of Great Britain and that done along our New England coast while he was here as a Henry Fellow, has extended our knowledge of the ecology of salt marshes, the last four chapters, on ecology, notably enhance the value of the book. His discussions of marine and fresh water ecology and especially of the ecology of salt marshes, while in part compilations, are in part original work and throughout show the effective evaluation and interpretation of one thoroughly familiar with the subject.

Finally, his chapter on ecological factors, geographical distribution, and life form, with its encouraging simplicity and directness of presentation, will prove an especially helpful introduction for those to whom this confused and controversial field with its extravagant and elaborate terminology has seemed unduly awesome and discouraging.

FUNDAMENTALS OF PLANT SCIENCE.

By M. Ellen O'Hanlon. F. S. Crofts and Company, New York. $4.25. 9 x 6; xi + 488; 1941.

Having in mind that 70 per cent of the students registered in general botany courses do not expect to continue studies in botany, and that only a small proportion of the remaining 30 per cent will take more than one additional course, the author has prepared her book "to provide for adaptations and certain alternatives, so as to serve several types of courses." The volume is designed for a full year's work, either half of which may be considered a complete course.

The volume is well planned. After the introductory chapters, Part I deals with Classification; The plant as a whole; The plant cell; Leaves; The flower; Fruits; Seeds and seedlings; Roots; and Stems: Part II with Alternation of generations; Algae; Fungi and their allies; Bryophyta; Pteridophyta; Gymnospermae; Angiospermae; Genetics; Organic evolution; and Botanical history. The large number of figures (268) have been carefully chosen and include pictures of famous botanists, beginning with Theophrastus, "the father of the science of botany," and ending with those of recent times. Brief sketches are included of those who have done pioneer work in the various fields of botany. Suggestions for investigation and discussion and lists of references conclude each section, a lengthy glossary is provided, also a good working index.

For a general culture course in botany and, indeed, for courses designed to provide a foundation for advanced work this volume will be found useful. It is direct in its treatment and stimulating, but it does not confuse the student with controversial problems which the advanced worker is more capable of comprehending.

PLANT HUNTERS IN THE ANDES.

By T. Harper Goodspeed. Farrar and Rinehart, Inc., New York and Toronto. 9½ x 6; xvi + 429; $5.00.

The culmination of the author's search for a lost species of tobacco plant came in an expedition to South America in 1935–36 which was followed by another in 1938–39. The experiences and accomplishments of the members of these two expeditions sent out by the University of California Botanical Garden are described in this book. With his wife and eight North American botanists and assistants the author covered thousands of miles up and down the west coast of the southern continent. In their quest for new and rare ornamental plants, the members of the expedition, motivated largely by the love of plant collecting, were carried from the arid coastal deserts of northern Peru and Chile, through the tropical and temperate rain forests, up the steep slopes of the snowy Andes to the top of the world, Aconcagua (the highest mountain in the Western Hemisphere), and from near the equator on the Ecuadorian border, to far southern Chile—the land of the weird monkey puzzle tree—and out into the South Pacific to Juan Fernandez, "Robinson Crusoe's Isle."

The book contains many excellent photographs illustrating the landscapes and peoples as well as the remarkable vegetation of the Andes. The personal and refreshingly informal fashion in which the story is told makes it interesting and enjoyable reading for the botanist as well as the general reader.

PLANTS COLLECTED BY R. C. CHING IN SOUTHERN MONGOLIA AND KANSU PROVINCE, CHINA. *Smithsonian Institution, U. S. National Herbarium, Volume 28, Part 4.*

By Egbert H. Walker. U. S. Government Printing Office, Washington, D. C. 30 cents. 9¾ x 6; 563–675 + 7 plates + 1 folding map; 1941 (paper).

In 1932 the National Geographic Society sent Doctor F. R. Wulsin to China to conduct its Central China Expedition. The objective was to collect ethnological, zoological, and botanical material, and to make a

general survey of the region preparatory to more intensive exploration at a later date. R. C. Ching, of the National Central University, Nanking, was chosen as the botanist of the expedition.

Ching gives an interesting account of his travels and experiences, and of the vegetation of the territory surveyed. Over 1,150 botanical specimens were collected, representing 2 families, 12 genera, and 22 species of pteridophytes, and 81 families, 318 genera, and 767 species of seed plants. About 25 new species and varieties have been based on Ching's Kansu specimens. Most of the new forms have already been described in various publications but the present systematic enumeration includes three original descriptions. This list adds much to the previous rather meager knowledge of the flora of this part of China. The work concludes with an index.

HUNGER SIGNS IN CROPS. *A Symposium.*

Edited by Grove Hambridge. The American Society of Agronomy and The National Fertilizer Association, Washington, D. C. $2.50. 10 x 7; xiii + 327; 1941.

Many so-called plant diseases such as "fired corn," "rust" in cotton, and "die back" in citrus fruit trees are merely hunger signs or symptoms of plant food deficiencies. The purpose of this book is to enable the farmer and other agriculture workers and all interested laymen to recognize the signs of nutritional deficiencies in crops so that they may be in a position to correct the difficulties themselves or seek further expert help from scientific workers in this field. Deficiencies in a considerable number of important crops, such as tobacco, corn and small grains, potato, cotton, vegetables, deciduous fruits, citrus fruits, legumes, are discussed in a practical, understandable manner. Some of the chapters include a key for quickly identifying a deficiency by its symptoms. The excellent plates also simplify identification. Each chapter has a list of selected references and the volume is well indexed.

WORK BOOK IN GENERAL BOTANY. *A Problem Approach to Plant Science Through Observation and Discussion.*

By H. C. Sampson. Harper and Brothers, New York and London. $1.75. 11 x 8½; vi + 242; 1941 (paper; loose-leaf).

A fourth reprinting of an excellent guide, which first appeared in 1935. It is designed for a two-semester course for college freshmen and is printed on one side of durable loose-leaf sheets, with plenty of space between the topics for the student's notes of observation. Instruction is almost entirely by the question method. Although the general education of the student has been mainly considered, the completed work will give to those who wish to take advanced courses a sound grounding in basic principles.

The numerous illustrations throughout the text are carefully chosen and well executed. Graphs and tabular matter and reference lists are also provided. There is no index, but the table of contents has been arranged to make textual matter easy to find.

LABORATORY PLANT PHYSIOLOGY. *Second Edition.*

By Bernard S. Meyer and Donald B. Anderson. D. Van Nostrand Company, New York. $2.00. 10¾ x 8½; iv + 101; 1941.

This laboratory manual has been designed on the same basis as the text book of *Plant Physiology* by the same authors. The first part deals with simple experiments in physical and colloid chemistry. The remainder covers very adequately the entire field of plant physiology. Special emphasis is placed on water relations and translocation. A total of 177 experiments are included. The majority of these are of an elementary kind but others introduce more elaborate quantitative methods. The instructor thus may select experiments best suited for elementary and advanced students and for a one or two term course. The book also includes several illustrations of apparatus, descriptions for the preparation of reagents and blank pages for the student's data and notes.

It is the opinion of the reviewer that this is one of the most practical and carefully prepared manuals in plant physiology available in published form.

HOSTS OF THE SUGAR CANE GUMMING DISEASE ORGANISM. *La Revue Agricole de l'Ile Maurice, Vol. 20, Number 1, 1941.*

By G. Orian. The General Printing and Stationery Company, Port Louis, Mauritius. 9¾ x 7; 19–58 + 6 plates; 1941 (paper).

Until fairly recently the gumming disease caused by *Bacterium vasculorum* was known only as a disease of cane sugar. In 1932 the author of the present work studied a disease of maize noticed in Mauritius. The pathogen was found to be *B. vasculorum*. Since that time other investigators have found the white palm to be a natural host for this bacterium on the island. The characters and reactions of the bacteria isolated from these hosts—cane sugar, maize, and white palm—are described. Orian likewise succeeded in inoculating Job's tears, guinea grass, the tall bamboo and the coconut palm with *B. vasculorum*. The results of his experiments with these artificial hosts are presented and illustrated.

VEGETABLE GROWING. *Third Edition, Thoroughly Revised.*

By James Edward Knott. Lea and Febiger, Philadelphia. $3.25 net. 7¾ x 5¼; 356; 1941.

Primarily a textbook for students in agriculture this book will be found of great value to all Victory gardeners, especially those who lack a knowledge of the basic principles and the "why and wherefore" of the various cultural operations. Only when the gardener is well grounded in these fundamental operations is he able to apply the specific cultural methods of each individual vegetable successfully.

This book is a masterpiece in concise, clear diction. The third edition is timely and should be instrumental in increasing vegetable production both commercially and in home gardens.

MORPHOLOGY

CONTRIBUTIONS TO EMBRYOLOGY. *Volume XXIX, Nos. 179 to 186. Carnegie Institution of Washington Publication No. 525.*

Carnegie Institution of Washington, D. C. $4.50 (paper); $5.50 (cloth); 11½ x 9; 193 + 56 plates; 1941.

The current issue of this valuable series contains 8 papers of considerable interest. The first two are concerned with descriptions and measurements of ova recovered from the rhesus monkey. Hartman and Corner figure two ovarian eggs (two plates) showing respectively the first maturation spindle, and the first polar body and second maturation spindle. Such fortunate recovery has made it possible to demonstrate clearly for the first time that in the monkey, as in the majority of mammals, the first maturation division occurs within the Graffian follicle just prior to its rupture. The recovery of 8 tubal ova of known ovulation age by Lewis and Hartman brings the total number described by them up to 12. Of the new series two were in the 2-cell stage, and six were non-fertile. Attempts to fertilize two *in vitro* proved unsuccessful. One plate of photographs from a motion picture of one of the 2-cell eggs shows the behavior of the centrosphere material before and during early cleavage.

The third paper by Heuser and Streeter is a remarkably complete record of the development of the Macaque embryo beginning with the free blastocyst and ending with the earlier fetal stages. The embryos represent closely over-lapping stages of known ages, accurately oriented and histologically ideal. Such data obtained and handled with superior laboratory facilities are particularly valuable in the interpretation of human material. Realizing that "the embryo at all stages is a living organism and is to be analyzed as a biologic problem rather than purely a morphologic abstraction" the authors have given us more than the customary descriptive study. From this point of view what were thought to be vestiges of great phylogenetic importance appear to be, in many instances, temporary embryonic structures essential to a particular period of development. The paper is completely and superbly illustrated with 33 plates and 5 text figures.

Three papers deal with human material. Two human ova of the pre-villous stage, having an ovulation age of about 11 and 12 days respectively are described and figured (8 plates, 4 text figures) by Arthur T. Hertig and John Rock. The welcome acquisition of two such beautifully normal ova enable one to complete the hitherto unfinished picture of development in man on the 11th and 12th days following fertilization. Two well-preserved, normal human embryos, one in the primitive-streak stage (Jones-Brewer Ovum I), the other an early presomite embryo having no primitive streak (the Torpin ovum) are described and figured respectively by Jones and Brewer and Joseph Krafka, Jr. The estimated age of the Jones-Brewer embryo is 18½ days. In addition to the primitive groove, allantois, and blood-vessel formation, it has a minute head-process—the earliest stage of the head-process yet described in human material. The Torpin ovum represents one of the best specimens on record of the simple villous group. In placing it in its correct position among the stage II embryos of Group I (Streeter's seriation) interesting comparisons are made with various previously described human ova.

A paper on the "Growth and development of the Orang-utan," by Adolph H. Schultz, with one plate and 14 text figures, supplies much new information on the conditions of growth and development of this important member of the anthropoid apes. Based upon observations and measurements on the outer body and on the skeleton and teeth of large numbers of specimens from many localities, this paper gives us a record of changes which occur with age in the body of the orang-utan. Comparisons, as far as accumulated data allow, show that in general the autogenetic processes of the orang-utan and the chimpanzee are far more similar than are those of either of these apes and man.

In a paper by I. Gersh and Arthur Grelman (3 plates, 1 text figure) a detailed study was made of the vascular pattern in the adrenal glands of rats and mice of various ages and under the influence of various degrees of stimulation (e.g., thyroid feeding, exposure to low temperature). The changes in pattern are interpreted in terms of function, and a physiological basis is established for the specific vascular pattern observed. Deductions are drawn which offer an explanation of the arrangement of the cells into zones in different animal species and under different physiological conditions.

THE RETINA. *The Anatomy and the Histology of the Retina in Man, Ape, and Monkey, Including the Consideration of Visual Functions, the History of Physiological Optics, and the Histological Laboratory Technique.*

By S. L. Polyak. The University of Chicago Press, Chicago. $10.00. 10½ x 7½; x + 607 + 100 figures; 1941.

This book represents a courageous and persistent, not to say stubborn effort, to find an explanation for the complexities of visual function in the complexities of retinal anatomical structure. How successful this effort has been it is impossible for the reviewer to say for the writing is most obscure. Beyond any doubt, however, the author has added many details to our knowledge of the arborization and synapses of the retinal neurones.

What makes the writing so obscure is the effortful and highly unsuccessful attempt of the author to be rigorously critical in his analysis. The "ands, ifs and buts" are piled many stories high, but little distinction made between those reservations that are solidly based and those that are merely frivolous hair splitting. Furthermore, the author fails to apply any critique to the interpretation of the histological pictures that he describes. In the histological technique used, the tissue is killed, some components are precipitated out of its colloidal jelly, others extracted. Upon surfaces which persist or develop through these treatments metal ion films are deposited. The deposition is determined by surface electrical forces which, to say the least, are not identical with those present in the living tissue. These metallic deposits, made visible by reducing the metal ions to the free metal, are examined in histological sections. What the author sees he calls cells, axones, dendrites, synapses, etc. What he actually sees is not tissue components at all but a system of artefacts related in varying ways to structural components of the tissue. This is not to be taken as implying that histological study is meaningless. On the contrary, the point is that histological data have an indirect and variable relation to tissue structure and critical analysis should give different weight to different aspects of the histological picture. Moreover, the author assumes that because certain cell processes appear axon-like while others appear dendrite-like, he can conclude that in the living state nerve impulses travelled away from the cell body in the former, toward the cell body in the latter. Uncritical assumptions of this type lie at the basis of much work in the field of cellular neurohistology and the author might well be pardoned for omitting a discussion of limitations in this field if he were in fact merely presenting a histological study. Such omissions cannot be condoned, however, in a serious attempt to relate structure to function.

In addition to its histological portion, the book contains 130 pages of bibliographical titles which should be extremely valuable to students in this field. There is also an extensive section on the history of physiological optics which contains many items not readily accessible elsewhere.

A MANUAL OF EMBRYOLOGY. *The Development of the Human Body. Second Edition.*

By J. Ernest Frazer. Williams and Wilkins Company, Baltimore. $9.00. 9⅛ x 6¼; x + 523; 1941.

The stated aim of the author is to provide a connected mental picture of the development of the human embryo. The book's outstanding feature is the application of the regional method so widely used in gross anatomy to a description of embryonic development. The relation of the developing parts to one another and to the whole organism is clearly explained throughout the various transformations. The description is fairly generalized so that the main outlines are not obscured by masses of detailed information. The text is illustrated with numerous well-chosen sections, reconstructions, and diagrams. Changes include such matters as rearrangement and addition of figures, with corresponding revision of the text, and the occasional introduction of new material, as in the case of the foetal circulation.

The book is divided into two parts. The first section deals with the early generalized stages of development, covering such topics as maturation, fertilization, segmentation, implantation, and formation of the embryo, with the establishment of the principal organs and systems. The embryonic membranes and placental circulation are described, and the general aspects of growth and differentiation are considered. The second portion deals with organogenesis, and the history of specific regions and systems. An index is appended, but no bibliography, references being included in the text itself.

This book should be a valuable source of reference for anatomists, advanced medical students and teachers of embryology. The treatment does not seem appropriate for use as an introductory text.

HEARING AND EQUILIBRIUM.

By H. Macnaughton-Jones. The Williams and Wilkins Company, Baltimore. $2.50; 8¾ x 5⅞; vii + 128; 1940.

After two centuries of fairly intensive research by anatomists, physiologists, physicists, and otologists in general, the mechanism of hearing has yet to be satisfactorily clarified. As all know, the main difficulty arises from the smallness of the hearing organ and the remarkable complexity of its structure. To avoid this difficulty the author has proceeded to an investigation by constructing simplified models of parts of the auditory apparatus and on the basis of the models he

seeks to explain some of the characteristics of the phenomenon of hearing. The models are certainly ingenious and a thorough familiarity with acoustics is shown by the author. Unfortunately, the results reported here cover only small and uncoordinated details of the hearing mechanism and the problem of equilibrium is hardly touched at all. With respect to hearing the author features particularly the transmission of the sound wave to the internal ear. In his opinion he demonstrates that the sound wave passes through the pars flaccida of the tympanic membrane to the middle ear and then into the cochlea by means of the round window. This hypothesis, advanced by others years ago, cannot be fully accepted until an explanation of pertinent pathological and experimental observations on man and other animals can be found, for example, the hearing improvement produced by immobilizing the round window, or the hearing loss due only to interference with the ossicular chain. It may be that the author has developed the correct methodological approach to the problem but before his results acquire significance they must be integrated with the knowledge already at hand about the phenomenon studied.

LABORATORY MANUAL IN ANATOMY AND PHYSIOLOGY. *By Caroline E. Stackpole and Lutie C. Leavell. The Macmillan Company, New York.* $1.50. 11 x 8½; 214; 1941 (paper).

This well-organized manual was prepared primarily for use in conjunction with Kimber, Gray and Stackpole's *Textbook of Anatomy and Physiology*, but the exercises are of such a general nature that they can be profitably used with any standard text. The materials are organized around five very broad and logical topics: (1) physiological and anatomical organization and integration; (2) correlation and coordination of external activities; (3) correlation and coordination of internal activities; (4) adaptive responses and the special senses; and (5) reproduction and embryology. Space for student drawings, notes, and comments is included.

Where human material is impractical for dissection and observation, wise use is made of several other vertebrates, notably the frog and the rat. Although some attempt has been made to present the subject from a comparative point of view, this aim has largely been sacrificed to detailed instruction for dissection. The authors' evasion of references to human material in the section on reproduction and embryology is sufficient reason for suggesting that the title "Exercises concerned with human reproduction and embryology" should read "Exercises concerned with vertebrate reproduction and embryology."

The work is outlined in a detailed table of contents, and carries an appendix listing methods for preparing various laboratory materials and apparatus.

PHYSIOLOGY AND PATHOLOGY

IMMUNIZATION TO TYPHOID FEVER. *Results Obtained in the Prevention of Typhoid Fever in the United States Army, United States Navy, and Civilian Conservation Corps, by the Use of Vaccines: Influence of Antigenic Structure and Other Biological Characters of E. typhosa on the Production of Protective Antibodies in the Blood of Immunized Individuals: Increases in Protective Antibodies in the Blood Following the Use of a Single Small Dose of Vaccine for Reimmunization Purposes as Compared with the Use of Three Doses. The American Journal of Hygiene Monographic Series, Number 17, September, 1941.*

From the Research Laboratories of the Army Medical School, Washington, D. C. The Johns Hopkins Press, Baltimore. $2.50. 9 x 5⅞; xi + 276; 1941.

It is the purpose of this excellent monograph to report in detail a somewhat extensive series of experimental investigations participated in by members of the technical staff of the Medical Department Professional Service Schools, U. S. Army, during the period of 1934–1940, with respect to certain antigenic and immunizing properties of selected strains of *E. typhosa*. These investigations were undertaken with the primary objective of determining whether it might be practicable to still further enhance the protective properties of the typhoid vaccine distributed to the Army and also to discover whether or not the generally accepted hypotheses concerning some of the elements of the immune process might be applicable to the problem of immunity to typhoid fever. The textual material is presented in sections, as follows: Introduction, Historical review of the use of typhoid vaccine in the Army, Navy, and Civilian Conservation Corps, Experimental investigations undertaken, Antigenic characteristics of strains of *E. typhosa*, Relative protective potency of vaccines prepared with virulent and with avirulent strains of *E. typhosa*, Duration of immunity subsequent to immunization with typhoid vaccine, revaccination, and miscellaneous experimental observations. The appendix contains a wealth of descriptive and tabular information concerning techniques, standards, controls, protocols, and bacterial strains used in the experimental procedures upon which the report is based. The book contains a bibliography, but no index. The publication of this report has been awaited with interest and the results of the study made by the Army should have an important bearing on present and future attitudes toward the general problem of immunity and the specific problem of immunity to typhoid fever.

APPROVED LABORATORY TECHNIC; *Clinical Pathological, Bacteriological, Mycological, Parasitological, Serological, Biochemical and Histological. Third Edition.*

By John A. Kolmer and Fred Boerner and Collaborators. D. Appleton-Century Company, New York and London. $8.00. 9⅝ x 6½; xxvii + 921; 1941.

Little that is written here could add to or detract from the merits of this widely-accepted and well-established volume of approved laboratory procedures which has already enjoyed three editions within a ten-year period. Here, within the covers of a single book, are found complete, authentic and detailed clinical, pathological, bacteriological, mycological, parasitological, serological, and biochemical methods and techniques. The authors have succeeded throughout in striking a proper balance in the amount of detail given to fulfill the needs of the laboratory technician without being burdensome to the expert. Throughout the book an emphasis has been placed on the importance of using accurate and reliable apparatus and reagents. Special stress is also placed on quantitative tests and reactions, and in qualitative tests an effort is made to suggest a uniform terminology and methods for reporting reactions. Among the many new and approved methods included in this edition (all of which have been placed in the appendix), may be mentioned Quick's methods for the quantitative determination of prothrombin and for the estimation of hippuric acid in the urine, Sparkman's method for the determination of urobilinogen in the urine and feces, the simplified Kolmer complement fixation test for syphilis and the Eagle modification of the Wassermann test, methods for the determination of vitamin C in urine and plasma, and methods for the determination of sulfanilamide and other sulfonamide compounds in the blood and urine. A number of distinguished and experienced authorities are listed as collaborators in the preparation of the book. References are given at the end of some of the chapters, but usually as footnotes. The book is appropriately illustrated with numerous photographs, line drawings, tables, charts, and color plates. A complete index has been provided. This book is enthusiastically recommended to medical students, physicians, teachers, clinical pathologists and laboratory technicians, to all of whom it should prove invaluable.

BEHIND THE MASK OF MEDICINE.

By Miles Atkinson. Charles Scribner's Sons, New York. $3.00. 9¼ x 6¼; xiv + 348; 1941.

In the words of the author this book is about "Medicine in its broadest aspects, about its influence on the rise and fall of civilizations as well as about its influence upon the lives and deaths of citizens." The first chapter discusses epidemics as they have affected the course of history. The second chapter is a brief history of the medical arts and sciences of "the Amazing Century: 1840–1940." In Atkinson's opinion the Medical World, like the industrial since the Industrial Revolution, "is still bewildered by this new-found knowledge which has come so quickly that as yet it has not been properly digested." The author has a sense of humor and the happy faculty of seeing the viewpoint of the doctor and the viewpoint of the patient, and he uses this understanding in the subsequent chapters. These deal with diagnosis and history-taking; prognosis, which includes a sane discussion of euthanasia; clinical medicine, excesses in surgery, the overgrowth of specialism; ethical and unethical practice; the plight of the hospitals, and socialized medicine. Among the specific problems discussed are the amount and kind of explanation the doctor should give the patient with reference to his diagnosis; the "know-it-all" type of patient and the taciturn "you-tell-me" patient; the relative advantages of large and small hospitals; and when the removal of the appendix or tonsils may be harmful. The final chapter on "The Future" closes with the sentences:

> This one [civilization] appears to have had its day and to be bent only on its own destruction. . . . At least we can comfort ourselves with the knowledge that, if our present civilization is to die, it has made great strides in the six hundred years of its being, and will hand on to the next a tradition of scholarship worthy of that which Greece and Rome bequeathed to it. And medicine will go on. The sick still have to be tended though the days are dark. Medicine may even prove to be the link that will join the old age to the new.

COMMUNICABLE DISEASE CONTROL. *A Volume for the Health Officer and Public Health Nurse.*

By Gaylord W. Anderson and Margaret G. Arnstein. The Macmillan Company, New York. $4.25. 9¼ x 6¼; x + 434; 1941.

Communicable disease control presents two rather distinct problems—protection of the individual and protection of the community. This volume is written principally from the standpoint of the community. While personal protection has not been neglected, emphasis has been placed on those procedures which are designed to protect the population as a group rather than merely the individual. The authors have kept in mind the problems that confront the health departments, the schools, the visiting nurse associations, and other community agencies. An attempt has been made to evaluate the various control measures as to their relative effectiveness and to outline programs that will yield the greatest return in terms of necessary expenditure. The discussion of control measures is limited to those that are applicable under the conditions which confront the health department, and no effort has been made to consider details or techniques included in hospital care. In the first part of the book, such subjects as the historical considerations, control measures, administrative agencies, the rôle of the public

health nurse, and the legal basis of communicable disease control, are considered. In the second part, the prevention and treatment of the individual important communicable diseases are discussed in detail. A list of suggested readings is placed at the end of each chapter. The graphs and tabular material add to the value of the volume. There is a complete index. This authentic, complete and engagingly-written book should be of considerable value to schools, health departments and other public health agencies for whom it is designed.

DISEASES OF THE BLOOD *and Atlas of Hematology: With Clinical and Hematologic Descriptions of the Blood Diseases Including a Section on Technic and Terminology. Second Edition, Revised and Enlarged.*

By Roy R. Kracke. J. B. Lippincott Company, Philadelphia and London. $15.00. 10¼ x 7; xxiv + 692; 1941.

During the four years since the first appearance of this now indispensable *Atlas* much new material has accumulated which it has been necessary to incorporate within its pages. The revision and extension includes new material on fractionation of liver extract, a new chapter on hemolytic anemias, a new chapter on hemoglobinuria, new material on the action of drugs on the blood, a new section on hemoglobin and its derivatives as well as the porphyrin compounds, and recent work on bone marrow. The sections on blood transfusion, the operation of a blood bank, and the use of blood plasma have been treated in a comprehensive manner. The revision also includes matter which was omitted from the first volume concerning osteosclerotic anemia, achrestic anemia, ovalocytosis, Hodgkin's disease, and histoplasmosis. A complete section is devoted to vitamin K. In the chapter on the treatment of leukemia recent advances in the use of radiation and radioactive isotopes have been included. The last section (84 pages) is devoted to hematologic technique.

The bibliographies (at the end of each chapter) have been brought completely up to date and new illustrations have been added. There are now 54 colored plates in the volume, and 46 other figures. The index has received the same careful treatment in its revision as has the textual matter.

HISTORY OF PHARMACY. *A Guide and a Survey.*

By Edward Kremers and George Urdang. J. B. Lippincott Company, Philadelphia, London, and Montreal. $4.50. 9 x 6; ix + 466; 1940.

The history of pharmacy is really the history of the human race, for in no other phase of human endeavor do we get a clearer picture of man's ingenuity pitted against the challenge of race extinction than in the development of the art of healing. There has been a real need for a history of pharmacy which would go beyond the mere listing of chronological happenings, and present the subject in a truly integrated fashion. This volume amply fulfils the need. The wealth of material, well organized and completely presented, testifies to the enormous amount of painstaking labor involved in the preparation of the book. The essential facts pertinent to the history of the preparation and use of pharmaceuticals from the days of ancient civilizations, through the dark ages and the renaissance, down to the present day are set forth in concise scientific language and in an authoritative manner. The mutual relationships of pharmacy to medicine, education, industry, and the evolution of society in general are treated in detail. Special note is made of the development of pharmacy in several countries, particularly Italy, Germany, and the United States, while the growth of pharmaceutical schools and societies in this country, and the present tendencies toward uniformity in requirements, professional education, and state board examinations are given special attention.

With an eye toward the possible pedagogic use of the text, the authors have included a bibliography for each chapter, a chronology of pharmacy, a lengthy glossary, and a complete index.

VITAMIN K.

By Hugh R. Butt and Albert M. Snell. W. B. Saunders and Company, Philadelphia and London. $3.50. 8½ x 5½; x + 172; 1941.

This little volume should be heartily welcomed by physicians and investigators alike, because it presents the pertinent data in relation to one of the most newly-discovered and most important of the vitamins. The authors here set forth in a most acceptable fashion the history of vitamin K, the essential facts with respect to its chemistry and physiologic activity, and such data concerning its clinical use as experience to date has proved expedient. The first part of the discussion is concerned with general information, i.e. the discovery, distribution, methods of preparation and of assay, chemical aspects, and properties of the anti-hemorrhagic vitamin. Then follow, in order, sections on the coagulability of the blood, products which exhibit vitamin K activity, the hemorrhagic diathesis of patients having jaundice, biliary fistula, or hepatic damage, of those patients with certain intestinal disorders, of the newborn infant, and finally, the hemorrhagic diatheses not related to deficiency of prothrombin. The book is illustrated with numerous graphs and tables. A list of 350 important references is given at the end of the volume, and there are complete bibliographic and subject indices available. While intended primarily for the physician and the seasoned investigator, this mono-

graph is a notable contribution to our generally accessible literature on the all-important vitamins, and consequently should be well received in the scientific field.

THE MEDICAL ASPECT OF BOXING.

By Ernst Jokl. J. L. Van Schaik, Ltd. Pretoria. 17s. 6d. 8½ x 5½; 251; 1941 (paper).

It is the author's contention that boxing is a dangerous and, therefore, an undesirable form of physical education. To prove his point he here presents a collection of published case reports, observations and anecdotes dealing with boxing injuries, slight, permanent, or fatal. The physiologic and pathologic changes associated with the various traumae are enumerated and briefly discussed. It appears that lesions of the brain and nervous system are the most frequent, and particularly to be feared since the effects are not immediately manifest. The author realizes that any attempt to abolish boxing, even if the attempt were limited to schools and colleges, would meet with widespread opposition. Hence, he suggests at least more adequate rules regarding ring covering and ropes and the medical supervision of the boxers. Such precautions would still not eliminate the dangers of boxing since "the typical accidents are inherent to the sport as such. . . . . " Although one is impressed by the list of cases described they do not constitute definitive evidence to support the author's main plea. However, on the basis of the evidence given the whole subject certainly deserves a serious and thorough investigation.

THE VITAMIN CONTENT OF MEAT.

By Harry A. Waisman and C. A. Elvehjem. Burgess Publishing Company, Minneapolis. $3.00. 10¾ x 8½; ii + 210; 1941 (paper).

The aim of this timely, well-written and thoroughly documented book is to summarize the available information on the nutritive value of meat and meat products. The authors have reviewed the literature in a critical manner and only those results which appear to be most reliable have been included here. Individual chapters are devoted to the more important nutrients and each of the known vitamins comes in for authoritative analysis and discussion. Sufficient fundamental information is supplied in each case so that the value of meat in meeting the requirements of these nutrients can be considered in light of the most recent developments. The daily requirements listed for the individual vitamins and minerals are based on the values recently released by the Committee on Food and Nutrition of the National Research Council. Chapters on the preparation of the samples used and on the proximate analysis of the animal tissues have been included. A summary chapter is given which presents the general values for the vitamin content of the most important forms of meat products. Appended to each chapter is an extensive list of the literature cited. There is no index. This volume is recommended for its wealth of authentic and useful information on a subject of considerable general interest.

THE ADVANCING FRONT OF MEDICINE.

By George W. Gray. Whittlesey House, McGraw-Hill Book Company, New York and London. $3.00. 9 x 6; viii + 425; 1941.

This book is appropriately named. It is not concerned with the development of medical theory, but consists almost exclusively of a discussion of such phases of modern medicine as immunities, vitamins, allergies, blood pressure, haemophilia, influenza, sulfanilamide, pain, narcotics, cancer, and senescence. The reader who takes up the volume is not likely to put it down until he has finished it, and then it is probable that he will feel that all those questions that have been accumulating in the back of his mind have been adequately answered.

The thoroughness with which the author has covered his field is evidenced by the number of medical authorities whom he consulted and to whom he acknowledges his gratitude; the list of names covers more than four pages. There is also an extensive catalog of recommended reading and seventeen pages of index.

In one instance the author is guilty of a misstatement—this is when he states that George Fox was an epileptic. Fox was inclined to hysteria, and on one occasion suffered from an attack of hysterical blindness that lasted several days, but his biographers are agreed that he was not a victim of epilepsy in any sense. But this is a mere detail which does not detract from the value or interest of the book.

ENDOCRINOLOGICAL STUDIES IN THE BLUE WHALE (BALAENOPTERA MUSCULUS L.). *Hvalrådets Skrifter, Scientific Results of Marine Biological Research, No. 24.*

By Alf P. Jacobsen. Jacob Dybwad, Oslo. Kr. 8.00. 10¾ x 7; 84 + 8 plates; 1941 (paper).

The endocrinology of the cetaceans is an entirely virgin field of investigation, hence the present studies on the blue whale are a noteworthy contribution. The data herein presented were collected over a period of six years, during which time the author travelled as surgeon with a floating factory in the whaling areas of the antarctic. The investigation includes discussions on the gross and microscopic anatomy of the pituitary, thyroid, pancreas, adrenals, ovaries, and testes of the blue whale. A sufficient number of measurements and weights of the various organs is given to arrive at a

fairly definite idea as to their size. The investigation is concerned further with the preparation of various pure hormone extracts from the whale endocrines, and a study of their biological potency as compared with those from other animals. The fact that the whale endocrines were found to be quantitatively and qualitatively equal to the corresponding glands from cattle is ample reason for believing, as the author does, that the blue whale represents an enormous potential source of numerous important pharmaceuticals.

The monograph lists a bibliography of 101 titles, and carries a detailed table of contents. Numerous graphs, charts, tables, and photographic plates are presented in support of the textual material.

THE MICROBE'S CHALLENGE.

By Frederick Eberson. The Jaques Cattell Press, Lancaster, Pa. $3.50. 10 x 7; viii + 354; 1941.

Bacteriology as a science is not a subject dealing with static or fixed organisms following a uniform pattern of existence. Because of the recognition of this fact many important modern discoveries have been made. In like recognition of this fact, the dominant theme of this book is microbe *versus* man. In the same sense, it is the challenge of the microbe. The purpose intended is to narrate some of the highlights in the history of preventive medicine and to bring together in a logical form the fundamental principles upon which the modern bacteriological control of infectious diseases is based. Wherever possible, attempts have been made to clarify further the meaning of some technical terms by the use of word pictures or analogies. The author tells his story simply, honestly, and effectively. He believes that we have only just begun our battle with microbes, and his thesis seems to be that microbes are highly adaptable living things and that their adaptations, like those of other living things, tend toward their survival. Many of us do not realize how effectively microbes resist destruction. Particularly interesting are the author's discussions of the changeable characters of microbes, the startling discoveries regarding their chemistry, and the analysis of what constitutes their life and death. There is a short glossary, a list of suggested readings, and an index. Scientific specialists and intelligent layman alike will find the book fascinating and challenging—a thoroughly satisfying piece of reporting.

MICROBES WHICH HELP OR DESTROY US.

By Paul W. Allen, D. Frank Holtman, and Louise Allen McBee. C. V. Mosby Company, St. Louis, Mo. $3.50. 8¼ x 5½; 540 + 13 plates; 1941.

The stern necessities of life sooner or later lead us all by the route of cruel experience to understand that microbes have major rôles to play in the production of health, homes, food, clothes, fuel, and defense. In living, we must make use of, and defend ourselves against, many powerful agencies, and a solid knowledge of microbes is necessary if we are to avoid disease, hunger, exposure and oppression. This book, then, may be considered as the product of the average layman's need of becoming "microbe conscious." The authors have compiled here an amazing amount of information about man and his microbe friends and enemies. Some of the more interesting chapters have to do with the age of superstition, making the world microbe conscious, surgeons and microbes, the struggle against diphtheria, virus diseases, appendicitis, food poisoning, food preservation, friendly microbes, infections and sanitation on fur farms, and the bacteriophage. In addition, each of the common diseases caused by bacteria or viruses is discussed in detail. The illustrations, especially the series of 13 colored plates, are particularly well chosen. A carefully selected bibliography is appended to the book and an index has been provided. All in all, this interesting presentation of bacteriologic information should have a wide appeal to the general reader.

HANDBOOK OF COMMUNICABLE DISEASES.

By Franklin H. Top and Collaborators. The C. V. Mosby Company, St. Louis. $7.50. 9 x 6; 682; 1941.

This complete, authoritative and well-written book is intended as a text or handy reference for all persons whose professional duties necessitate contact with certain communicable diseases or infestations. An attempt has been made to present the material in as concise and handy a manner as possible. The chapters on pneumococcic pneumonia, tuberculosis, syphilis, and gonorrhea are somewhat longer than would be anticipated in a handbook, but the paramount importance of these diseases from both a curative and a preventive standpoint would seem to justify the additional space accorded them. The various diseases discussed have been classified by common portal of entry, a method which is unusual but one that should prove helpful. Under the respiratory portal of entry, the diseases have been further classified alphabetically into those caused by bacteria and those caused by viruses. Two chapters of unusual interest are concerned with the management of communicable diseases in the home and in the hospital. The book is illustrated with excellent clinical photographs and a series of ten color plates. A list of helpful references for further reading is appended to each chapter in the book. The appendix provides in tabular form much valuable data on associated conditions and complications and differential diagnosis. A glossary and a complete index conclude the volume.

ANNUAL REPORT FOR THE YEAR 1940: DIVISION OF TUBERCULOSIS CONTROL. *The Bulletin of the British Columbia Board of Health. Volume 11, Appendix No. 1, 1941.*

By W. H. Hatfield. Provincial Board of Health, Victoria, B. C. 10¾ x 8⅜; 166; 1941 (paper).

This document includes descriptive, statistical and pictorial presentations of the work being done in the fight against tuberculosis in this particular province of Canada. The introduction discusses such matters as case finding, treatment, follow-up work, rehabilitation, finances, health education, and the work with the Indians in the province. Then follow sections dealing with the district nursing program, social service, travelling clinics, and the Vancouver, Tranquille and Victorian units. The statistical portion of the report presents an extensive series of tables and charts concerning the institutional admissions and discharges, clinics, new cases examined, notifications of tuberculosis, and the comparative analysis of case status. There is a list of maps showing the incidence, distribution and mortality rates of tuberculosis in the province, and the report concludes with a special series of charts graphically illustrating the number of pneumothorax treatments, new and old cases examined by all clinics, x-ray examinations, the percentage distribution by age groups, the racial distribution, the total deaths from tuberculosis, and much other pertinent information. The volume is not indexed.

THE VALUE OF HEALTH TO A CITY. *Two Lectures Delivered in 1873 by Max Von Pettenkofer. Reprinted from Bulletin of the History of Medicine, Vol. X. Nos. 3 and 4, 1941,*

Translated from the German, with an Introduction by Henry E. Sigerist. The Johns Hopkins Press, Baltimore. $1.00. 10⅛ x 6⅞; 52; 1941.

As many public health administrators have from time to time realized there is apparently only one way besides an epidemic to move communities and countries to expend funds on preventive health measures. It is to point out, step by step, how such measures will eventually bring about financial returns in terms of more man-hours of work, and less sickness compensation, welfare aid, etc. In these two lectures delivered about 70 years ago at Munich Pettenkofer followed just this line of reasoning in pleading particularly for an adequate water supply system. He further bolstered his argument with an appeal to civic pride by emphasizing the lower mortality of London (which by that time had its water supply) in comparison with that of Munich. The author's cogent reasoning is valid to-day as it was then but otherwise these lectures cannot be considered as outstanding examples of Pettenkofer's contributions to medical science. As a matter of fact, Sigerist's introduction which includes a sketch of Pettenkofer is much more interesting reading.

ESSENTIALS OF ENDOCRINOLOGY.

By Arthur Grollman. J. B. Lippincott Company, Philadelphia and London. $6.00. 9 x 6; xiv + 480; 1941.

In this book a critical evaluation of all important aspects of the subject of endocrinology is attempted. Following a brief, initial chapter in which a basic survey of the field is made, the material is presented in five parts. In Part I, Endocrine glands of the cranial cavity, the bulk of the discussion is devoted to the hypophysis in its anatomical, physiological, pharmacological and pathological aspects. There is a brief discussion of the pineal gland. Part II, The branchiogenic organs, is devoted to the thyroid, the parathyroids and the thymus. In Part III, The endocrine organs of the abdominal cavity, the islet tissues of the pancreas and the adrenal glands are discussed. Part IV, The hormones of the reproductive Systems, includes a lucid and thorough presentation of this complicated field. In Part V, The hormones derived from the nonendocrine organs, a brief survey is made of current knowledge of hormones of the gastro-intestinal tract and other presumptive hormones (cardiac, liver extract, renal extract, heparin, etc.). Lists of pertinent references are appended to each chapter and there is an index. The book is illustrated with 74 figures.

A HISTORY OF MEDICAL PSYCHOLOGY.

By Gregory Zilboorg in Collaboration with George W. Henry. W. W. Norton and Company, New York. $5.00. 9¼ x 6; 606; 1941.

This excellent history of medical psychology is the result of a sixteen-year period of collecting and digesting basic and illuminating data. The material is presented throughout in the context of the social and ideological culture characteristic of the various periods described. Crucial advancements are high-lighted, so that the book is not merely a catalog of contributors and their contributions, but an intelligibly molded formulation of the dynamic forces which have culminated in the present-day concepts dominating this important field of human thought. There are fourteen chapters in all. The first twelve, written by Zilboorg, present a survey of medical psychology from primitive to modern times. The last two chapters, by Henry, are concerned with a brief account of the history of the differentiation of organic from functional mental disorders and with the transformation of asylums into hospitals. References are given in footnotes and there is a well-planned index.

BIOCHEMISTRY

CHROMATOGRAPHIC ADSORPTION ANALYSIS.

By Harold H. Strain. Interscience Publishers, Inc., New York. $3.75 9 x 6; x + 222; 1942

Many important advances in the natural sciences have depended upon the detection and isolation of specific, homogeneous chemical compounds. Chromatographic adsorption analysis is the separation of compounds with the use of selective adsorption. This powerful tool of analytical and synthetic research has remained much of a mystery to many because of the lack of a simple approach to the subject, which this book now affords. The importance for the biochemist of gentle methods of analysis and separation such as chromatographic adsorption analysis, electrophoresis, and ultracentrifugation which might be used on the labile compounds with which he works cannot be over emphasized.

Here is a simplified explanation of the theory, a very suggestive presentation of the many uses of the method for structural, inorganic and organic chemists, a first hand account of the careful techniques (including simplified illustrations of apparatus, formulae, and tables) and a very large bibliography (40 pages), all of which combine to make this an important handbook for workers in research and industry alike.

SEX

WOMAN'S PERSONAL HYGIENE; MODERN METHODS AND APPLIANCES.

By Leona W. Chalmers. Foreword by Winfield Scott Pugh. Drawings by Alfred Feinberg. Pioneer Publications, Inc., New York. $2.00. 8 x 5½; xii + 192; 1941.

After a brief description of the anatomy of the female organs associated with reproduction the author proceeds with her discussion of "intimate domestic hygiene." Included are such subjects as menstrual pain, leucorrhea, social diseases, vaginal hygiene, plastic surgery, etc. The specific value of the book lies in the intelligent descriptions of such procedures as enemas, vaginal douches, and postpartum and other exercises. The author is a physician's wife who has devoted many years to the study of feminine hygiene. Her book is simply and clearly written with little use of technical language, except in some quotations from medical authorities which she used to add authoritative weight and to reassure the reader with regard to some of her statements. It is written for the laywoman and the attitude taken is one of common sense.

BIOMETRY

THE HEARING OF SCHOOL CHILDREN. *A Statistical Study of Audiometric and Clinical Records. Monographs of the Society for Research in Child Development, Vol. VI, Serial No. 29, No. 3.*

By Antonio Ciocco and Carroll E. Palmer. Society for Research in Child Development, National Research Council, Washington, D. C. $1.00. 9 x 6; v + 77; 1941 (paper).

A report of a detailed summary of the results of an investigation which the U. S. Public Health Service has conducted on the hearing of Washington, D. C. school children over a 5-year period, beginning in 1931. Some of the findings have already been published but are herein included. The aims of the study were:

> First, to evaluate critically certain methods employed in studies of deafness in children. Second, to determine the degree of hearing impairment and the clinical and other factors associated with it. Third, to formulate a program which, it is hoped, will permit a conclusive contribution toward the solution of the problem of prevention of deafness.

Very nearly 14,000 children were examined with a Western Electric 4-A (phonograph) audiometer and over 1,400 children received a hearing test with a Western Electric 2-A (pure-tone) audiometer. About one half of the children in the latter group were examined twice, and over a third received three tests. Although the phonograph audiometer is satisfactory under laboratory conditions the results of the tests in the school environment seem to indicate that effort should be directed towards improving the instrument and methods of testing before the most satisfactory results can be obtained if a program aimed at the prevention of deafness in children is to be developed in the schools. During the 5-year period "fully 30 per cent of the ears with only a slight high tone loss and 25 per cent of ears with slight loss of tones of the conversational range deteriorated sufficiently to acquire a marked degree of the respective impairment." The rate of development of decreased perception for the tones of speech is greater in the younger than in the older children. In this type of impairment, in almost one half of the ears there was also present an overt and marked alteration of the otoscopic appearance of the tympanic membrane. The study points to the importance of therapeutic care as well as the prevention of middle ear infection. Tables and graphs exhibiting the results of the tests, form blanks, and a bibliography of 66 titles are included in the report.

STATISTICAL METHODS FOR RESEARCH WORKERS. *Eighth Edition, Revised and Enlarged.*

By R. A. Fisher. Oliver and Boyd, Edinburgh and London. 16s. 8¾ x 5½; xv + 344. 1941.

With the eighth edition of this textbook, the form and contents seem to have become more or less stabilized. One notes very little revision or further expansion of the preceding edition (cf. Q. R. B., Vol. 14, p. 264).

The 16 years that have passed since the work first appeared have seen changes in the viewpoint and attitude of statisticians towards the methodologic developments formulated by Fisher as well as to the contents of this work. With time and with the aid of texts published by others the confusion of ideas engendered in part by Fisher's unique expository style has to some degree lessened. Although for the uninitiated this will always be a difficult book, the more advanced student of statistics is enabled to find in it a clearer outline of the objectives of the recent analytic techniques than in the many other texts which presumably are prepared for elementary courses on the subject.

FAMILY EXPENDITURES IN THE UNITED STATES. *Statistical Tables and Appendixes.*

By the National Resources Planning Board. United States Government Printing Office, Washington, D. C. 50 cents. $11\frac{3}{8}$ x $9\frac{1}{8}$; xxi + 209; 1941.

This, the third in a series of reports prepared by the National Resources Planning Board on the basis of data from the 1935–36 Study of Consumer Purchases is the most detailed analysis yet made of family expenditures in the United States and includes a breakdown of these expenditures into over 90 categories of outlay, together with comparative estimates indicating farm, rural nonfarm, and urban differences, regional variations, and differences with respect to size of family, as between white and Negro families, and in relation to expenditures for durable goods. The statistical results are shown in the present volume both in summary form and in a more detailed set of reference tables. A description of the sources and methods used in the study is presented in an appendix.

THE BULLETIN OF MATHEMATICAL BIOPHYSICS. *Volume 4, Number 2, June, 1942.*

Edited by N. Rashevsky. University of Chicago Press, Chicago.

This number contains the following papers: A mathematical analysis of elongation and constriction in cell division, by H. D. Landahl; A fundamental form for the differential equation of colonial and organism growth, by Nathan W. Shock and Manuel F. Morales; A note on the diffusion of electrolytes in cells, by Alston S. Householder and Robert R. Williamson; Periodic phenomena in the interaction of two neurons, by George Sacher; A theory of electrical polarity in cells, by Robert Williamson and Ingram Bloch; An alternate approach to the mathematical biophysics of perception of combinations of musical tones, by N. Rashevsky.

PSYCHOLOGY AND BEHAVIOR

SELF-DIFFERENTIATION OF THE BASIC PATTERNS OF COORDINATION. *Comparative Psychology Monographs, Volume 17, Number 4, Serial Number 88.*

By Paul Weiss. The Williams and Wilkins Company, Baltimore. $2.00. 10 x $6\frac{3}{4}$; 95; 1941 (paper).

This paper is a contribution to the study of the problem of the ontogeny of motor coordination. Its stated objective is "to present direct experimental proof that the basic patterns of coordination arise by self-differentiation within the nerve centers, prior to, and irrespective of actual experience in their use". The experiments of the author which are analyzed with respect to their bearing on this matter, deal with the transplantation of limbs in amphibians. Weiss has previously shown that the transplantation of limbs in young amphibians, in such a way as to provide the transplant with motor innervation from a nerve branch of one of the normal host limbs, results, after transmissive connections have been established, in contraction of the muscles of the supernumerary limb *concurrently* with the contraction of the corresponding muscles of the normal limb. The phases of activity of a supernumerary muscle correspond precisely with those of the synonymous muscle of the host limb innervated from the same plexus. In the present work this "homologous response" of synonymous muscles or, as the author now proposes to call it, this "myotypic" response, has been utilized as an assay method.

In larval salamanders possessing functional limbs the two fore limbs were exchanged with the original dorsoventral orientation retained. Since the two limbs are mirror images of each other, this operation amounts to replacing one limb by another which has the same assortment of muscles but in exactly the reverse arrangement. After reinnervation the action of these limbs was studied by means of slow-motion pictures; and "myochronograms" giving the details of the activity of each muscle were constructed. This study revealed that, in the transplanted limbs the muscular movements were such as to indicate that the nerve centers were calling the individual muscles into action in the same rhythm, sequence and intensity as they had done when they were still operating normal legs with unreversed musculature. In doing this, however, the peripheral effects were just the opposite to those which would serve the organism; instead of progression, they produced regression. Nevertheless, this behavior was never altered by any adaptive change even though the animals were kept for long periods of time.

Similar experiments done with amphibian larvae in which the limbs were transplanted before the onset of function led to similar results. Such limbs, from the very onset of motility, moved in reverse. This indicates that the basic coordination patterns revealed in the previous experiments are not only ingrained in the centers after they are developed, but that they are originally developed without any constructive influence of experience. The centers develop and elaborate the patterns of coordination by pure self-differentiation. That sensory control plays no constructive rôle in the development and maintenance of these basic patterns

of motor coordination has been shown by further experiments dealing with de-afferentiation of limbs.

Weiss concludes that the basic repertoire of primary motor patterns exhibited by these forms arises by self-differentiation within the central nervous system independent of sensory control and guidance by experience. These patterns when later projected into an anatomically normal peripheral effector system, produce biologically adequate effects. If, however, they are confronted with an anatomically disarranged periphery they produce correspondingly distorted effects without signs of corrective adjustment.

The experiments upon which these conclusions are based are presented with the utmost clarity and the results seem to be unequivocal. The author has been very careful to distinguish between the factual content of the experiments and any speculative hypotheses derived from them. This clear-cut distinction makes it easy to evaluate the evidence presented, quite apart from its theoretical implications. When this is done, it seems to this reviewer that the author's fundamental conclusions concerning self-differentiation of the basic motor patterns are amply supported by the experimental results; are, in fact, almost inescapable. It must be emphasized, however, that the work applies specifically to the amphibia and that, as Weiss himself points out, the situation in higher vertebrates and particularly in higher mammals forms quite a separate problem. Some work on mammals which does bear upon the problem of motor coordination is briefly reviewed in this paper and Weiss believes that, despite the enormous number of acquired secondary patterns learned under the guidance of cortical activity which tends to obscure the old primary patterns in this group, here, too, such basic unlearned patterns do exist.

THE PSYCHOLOGY OF ARISTOTLE: *An Analysis of the Living Being.*

By Clarence Shute. Columbia University Press, New York. $2.00. 8½ x 5½; ix + 148; 1941.

Some years ago H. G. Wells stated that in general one could learn more about the world's great books by reading commentaries upon them than by reading the originals. Without committing ourselves to the acceptance *in toto* of such a broad statement, we can yet realize that it seems applicable to Aristotle's writings on psychology. This is partly because these were not integrated by the original author; they are scattered through five different documents.

The compiler of the commentary, like most modern students, perceives clearly the relation between psychology and biology, and believes the appreciation of the former to involve some general knowledge of the latter. Therefore he has carefully sifted all the biological and metaphysical works of Aristotle in order to glean material which he may consider indispensible to an intelligent comprehension of that writer's theories of the mental processes of man.

The quotations, however, are only the foundations on which the author has erected his own superstructure, which is a commentary on the development of human mentality, its resemblances and dissimilarities to that of the lower animals, the relation between mental and physiological activity, and finally the immortality of the soul. Whether Aristotle himself would have approved of this procedure is irrelevant; The Stagerite was the product of his age, and his thought was conditioned by his environment. Notwithstanding that for twenty centuries he dominated all fields of human thought, he yet needs an interpreter to be understood by modern minds—or rather, modern minds need an interpreter to understand him—and this need is well supplied by the present book. The reader who has assimilated it will be the better qualified to read Aristotle in the original for having done so.

There is an index of eight pages and an appendix containing an Analytical Outline of the same length.

SOCIAL INFLUENCES AFFECTING THE BEHAVIOR OF YOUNG CHILDREN. *Monographs of the Society for Research in Child Development, Vol. VI, Serial No. 28, No. 2.*

By Ruth Pearson Koshuk. Society for Research in Child Development, National Research Council, Washington, D. C. $1.00. 9 x 6; iii + 71; 1941 (paper).

In the present survey, which the author states is far from exhaustive, an effort has been made "to place in reasonable perspective the significant research publications since 1925 dealing specifically with the influence of social factors, broadly defined, on the behavior of young children. A number of unpublished studies known to the writer are included." The extensive literature concerning handicapped children is not included, nor are systematic psychologies, texts, and works of a popular nature, with a few exceptions. The discussions of the literature are grouped under four main headings: A. Social influences ignored or minimized; B. Social influences recognized but deplored; C. Social influences recognized: Suggestions for research, basic concepts, and method; D. Studies relating social influences to child behavior. Section D is broken down into ten categories, some of which we give, selected at random: Ecological studies and census-type surveys of social backgrounds; Comparison of behavior before and after marked environmental change; Mental growth careers and the predictive value of early tests; Experiments in social interaction:—observation under relatively controlled conditions; Longitudinal or genetic studies.

In a summary the author gives her interpretation of the direction in which studies of child development

and behavior are moving as revealed by her analysis of the literature. The extent of the literature covered is indicated by the list of 525 titles given in the bibliography. There is no index.

PSYCHOGENIC FACTORS IN BRONCHIAL ASTHMA. *Parts I and II. Part I. Psychosomatic Medicine Monograph IV. Part II. Psychosomatic Medicine Monographs, Volume II, Nos. I and II.*

By Thomas M. French and Franz Alexander and Collaborators. National Research Council, Washington, D. C. 10¼ x 6⅞; Part I, 92: $2.00. Part II, 236; $3.00 (paper).

This *Psychosomatic Medicine Monograph* embodies the results of a four-year cooperative study by the research staff of the Chicago Institute for Psychoanalysis with the assistance of four physicians specializing in allergy, of both psychogenic and allergic factors, found in patients with asthma. The first chapter is devoted to a discussion of asthma from the point of view of the allergist, and the second and third to a review of the literature on psychogenic factors in asthma. The remainder of the monograph presents the findings in 27 cases of asthma treated by psychoanalysis. The outstanding findings prominent in these cases may be summarized as follows: 1. The central emotional problem concerns separation from the mother. 2. There is a relation of asthma to suppressed crying for the mother. 3. The mothers of asthmatic children belong to the rejecting mother type. 4. Some mothers of asthma children show a marked pride in their children's early independence. 5. Asthma attacks often appear in very early childhood. 6. The sexual impulse seems to be most significant in precipitating asthma attacks. 7. Allergic patients, after they succeed in overcoming their emotional conflict about emancipation from the mother or her substitute, become more resistant against the allergens. Part II is devoted to a detailed presentation of the cases, including the course of the analysis, on which this study is based. The entire study is thoughtfully carried out and the stimulating findings are discussed in a conservative way. There is a bibliography of 43 titles.

INTELLIGENCE, POWER AND PERSONALITY.

By George Crile. Whittlesey House, McGraw-Hill Book Company, New York and London. $3.00. 9 x 6; vi + 347; 1941.

In this book the author presents the results of a comparative anatomical and physiological study of the energy-controlling system of man and animals, notably the brain, the heart and the blood, the thyroid gland, the adrenal glands, the celiac ganglia, and the sympathetic system. He postulates that variations in intelligence, power, and personality among the different species of animals and the races of man are determined by variations in the relationships of these organs to each other. In all, 3,734 animals, collected in the past ten years from all parts of the world, form the material of the study. The organs of each animal were weighed and weights relative to each other and to the total body weight computed. These data are presented in detail in tabular form in the appendix. The viewpoint throughout is mechanistic. The terms comprised in the title are used broadly and without any attempt at precise differentiation, "intelligence", for instance, being equated with relatively heavier brain weight, "power" with a relatively highly-developed sympathetic system, etc. The validity of the method which is used of comparing absolute organ weights of one animal of a species and one animal of another species, and drawing general conclusions as to the relative intelligence, power, and personality endowment of the two species is questionable. Nevertheless, the amazing mass of unique information presented is absorbing. In Part IV, Summary and conclusions, ten biological principals which the author believes account for the unique and variable intelligence, power, and personality of man and animals are listed and discussed. The book is indexed but does not include a list of references.

SOCIAL LEARNING AND IMITATION.

By Neal E. Miller and John Dollard. Yale University Press, New Haven; Oxford University Press, London. $3.50. 9 x 6; xiv + 341; 1941.

In this book imitative learning, as an item of human behavior, is studied from the double viewpoint of the psychological principles involved in its learning, and the social conditions under which this learning takes place. The first five chapters are devoted to a consideration of the learning process in general. Four basic factors in all learning are discussed, notably *drive*, *cue*, *response*, and *reward*. Beginning with chapter six, imitative behavior is the focus of attention. Three sub-mechanisms are described: *some* behavior, *matched-dependent* behavior (leader-follower relationship) and *copying*. Two experimental studies of imitative behavior are reported, one carried out on rats and one on children. The results in both cases demonstrate that imitation of a given response will be learned if rewarded, and generalized to new, somewhat similar situations. One chapter is devoted to a detailed discussion of matched-dependent behavior, and one chapter to copying with particular attention to the rôle of difference and sameness. A chapter of particular interest is that on social conditions producing imitation. Crowd behavior is discussed in the light of the tenents of the preceding chapters and on analysis of a lynching presented. There are two appendices,

the first devoted to a critical review of Holt's theory of imitation, and the second summarizes briefly (a) theories of other writers on the nature of imitative behavior, and (b) other experimental work on imitative behavior. There is an eight page list of references and an index.

INTRODUCTION TO PSYCHOBIOLOGY AND PSYCHIATRY. *A Textbook for Nurses.*

By Esther Loring Richards. C. V. Mosby Company, St. Louis, Mo. $2.50. 8½ x 5½; 357; 1941.

Out of her long experience in teaching the undergraduates of The Johns Hopkins Training School for Nurses, Doctor Richards has written this welcome and excellent textbook. The intention of the book is to promote an understanding of human behavior in its relationship to the practice of the nursing profession. The material is presented in two parts. Part I, Psychobiology—A study of the functioning in normal behavior, presents the fundamental concepts of the psychobiological viewpoint in the context of its historical position in man's way of looking at himself. The personality study, by means of which the nurse is given an opportunity to take stock of the personality equipment with which she lives, is discussed in detail.

Part II, Psychiatry or psychopathology, is devoted entirely to a descriptive presentation and discussion of the various reaction types which comprise the clinical material of psychiatry. Two chapters are devoted to the minor reaction types, or neuroses, and the remainder of the book to the major reaction types, or psychoses. The classification followed is that developed by Adolph Meyer. The discussion throughout is simple and lucid. A list of references is appended to each chapter and there is an index.

CHILDREN IN A WORLD OF CONFLICT.

By Roy F. Street. The Christopher Publishing House, Boston. $2.50. 7¾ x 5¼; 304; 1941.

This book has been prepared especially for the benefit of teachers and parents but will be found generally useful. The main theme is that in his daily life the child continuously encounters an environment which always possesses some new and strange qualities. Unless he is well equipped to meet these unusual conditions he may react through fear, surprise, or ignorance in a manner that does not meet the approval of the adult moiety. Therefore, the author pleads for a better understanding of the limitations of childhood and a greater flexibility in teaching methods both for school and home. To illustrate his point of view the author presents short case histories to describe the several types of childhood personality and the so-called problem children, and outlines pedagogic methods to overcome the difficulties. The style of writing as well as the author's obvious mastery of the subject serve to render this book effective for its purpose.

UNDERSTANDING YOURSELF. *The Mental Hygiene of Personality. Sixth Edition, Revised.*

By Ernest R. Groves. Emerson Books, Inc., New York, $2.50. 8 x 5¾; 279; 1941.

This book, which is now issued in a sixth and revised edition, presents a practical and common sense discussion of the mental hygiene of personality, designed to be useful to the average reader. The essence of wholesome personality is regarded as learning to live with one's self and to make good use of all one has for adjustment to the environment. The author's main and sound thesis is to know one's self as one is, accept one's self as one is, and on this basis utilize one's self to the utmost. The book is written in a simple, direct, unpretentious style. It should prove of interest to almost any adult reader.

DE OMNIBUS REBUS ET QUIBUSDEM ALIIS

CARNEGIE CORPORATION OF NEW YORK: REPORT OF THE PRESIDENT AND OF THE TREASURER *for the Year ended September 30, 1941.*

By Frederick P. Keppel and Robertson D. Ward. Carnegie Corporation of New York, New York. 9 x 6; 148; 1941 (paper).

The Carnegie Corporation of New York was established by Mr. Carnegie in 1911. It has for its purpose the advancement and diffusion of knowledge and understanding among the people of the United States and the British Dominions and Colonies. In addition to a review of the 1940–41 year's work, Keppel, who retired in November, gives an interesting survey of his nineteen years of service as president. He does not hesitate to point out where mistakes have been made. Comparing the general picture in 1941 with that of 1922, he says:

> . . . the following changes seem to the writer to be the most significant. In the first instance the place of the foundation in the whole picture of what may be termed cultural philanthropy has definitely changed. . . . While the total capitalization of foundations has risen, . .. the total income available for distribution annually has fallen. As to other sources of support, individual gifts are, for the present at any rate, dropping off, while public funds and the services and gifts of industry are furnishing a rising share of the total contributions. Foundations no longer avoid fields which will bring them into contact with government or business, but are eager to seek the cooperation of both.
>
> In 1922 foundation funds went predominantly to academic or quasi-academic recipients. Today there is a much wider spread. It is today realized that a

grant which helps only a single institution is not an ideal grant, and for that reason exemplary influence, or prestige if one prefers, is today deliberately given more weight in the selection of institutions than financial need.

. . . During these nineteen years the individual rather than the curriculum or the academic machinery has become the center of our thinking. More and more of our education is taking place outside the classroom. Libraries, museums, and other various agencies are cutting into the territority hitherto controlled by school or college. In all this the progress of adult education has been an important factor.

In 1922 the foundation was confident of its place of usefulness. It still has confidence today, but of a different kind. It has less trust in what money can do, far less certainty of its own wisdom, but it knows from experience that, while many of its most cherished plans may go astray, others will prove useful to humanity to a degree far beyond original hopes.

WORKING WITH THE MICROSCOPE.

By Julian D. Corrington. Whittlesey House, McGraw-Hill Book Company, New York and London. 1941. 9 x 6; xi + 418; $3.50.

Most books written for the purpose of providing instructions in microtechnique fall into one of two classifications—either they are frankly juvenile and unscientific or they are highly professional and technical. The author has prepared this manual for the large body of serious workers who fall in between these two extremes. Beginning with the simplest and proceeding by easy stages to advanced operations, the explanations have been made as detailed and nontechnical as possible. The volume not only tells the beginner how to use the microscope itself, but gives complete instructions on the preparation of slides or specimens of every degree of difficulty. Nearly every type of subject and field of interest is treated—from microfossils to textiles, from pond life to photomicrography, from soils to sections. In addition to the material on the preparation of slides, the book contains useful information about the microscope and its accessories, new methods in microscopy, short cuts, and special problems. The final chapter, giving full directions on the preparation and use of reagents, is especially valuable. The book is illustrated with many carefully-chosen photographs and line drawings. The appendix contains a list of sources of supplies, a bibliography, and reference tables. A complete index concludes the volume.

Working with the Microscope is heartily recommended as of interest to every amateur, hobbyist, and student —to everyone except the advanced professional—who wants to learn something of this fascinating science.

THE UNIVERSAL CONSTANT IN LIVING.

By F. Matthias Alexander. With an Appreciation by G. E. Coghill. E. P. Dutton and Company, New York. $2.50. 7⅜ x 5; xlii + 270. 1941.

After an honest attempt of three months duration to sift the verbiage of these pages for the point the author is trying to make, the reviewer must finally accept defeat, and admit that the *Universal Constant* is as elusive as the end of a rainbow. An understanding of the work should not be attempted by anyone who is less than a mental giant, because, to lesser minds, the strain of 260 pages of sentences similar to the following will undoubtedly lead to untold mental anguish.

The close connexion which I observed to exist between the processes of use and functioning, and which worked as I saw from the whole to the part, was sound evidence to me of an integrated working of the organism, and when in working to this principle I discovered the existence of a control of this integrated working, which, according as it was employed, influenced for good or ill my general functioning, I realized that I had not only come upon the primary control of the integrated working of the psycho-physical mechanism in the use of the self that I needed to bring about a change in my own reaction, but that, by the objective proof emerging from my observations and the procedures I employed, the concept of the organism-as-a-whole had been placed upon a foundation that could be scientifically established.

The author admits that it is as difficult for him to put his concept into spoken or written language as it is to describe the sensation red. This being the case, until a suitable mode of communication has been discovered, it seems useless for anyone to make such an attempt. The abundance of testimonial letters concerning the miracles wrought by the author's "technique" would appear more appropriate in an advertising column.

ONTOGENY AND SUCH AS ISOS.

By Melcherd H. Kutch. The Christopher Publishing House, Boston. $1.50. 7¾ x 5¼; 119; 1941.

There is very little about ontogeny in this book. Whether Isos is represented the reviewer is unable to say, for he has been unable to locate that word in any dictionary to which he has access.

The forty-two chapters which comprise this work are of unequal weight. Some consist of newspaper clippings about Lina Medina, Robert Wadlow, and the Dionne children, some consist of unorganized material (Lincoln's Gettysburg address is interpolated into an exposition of Egyptian cosmology), and some consist of nothing at all except the caption. It may be desirable to have the accumulated wax removed from one's ears, but why should such medical advice be united with a discussion of the brotherhood of man and the cost of relief?

On the whole the book contains much that is good and original, but "the parts that are good are not original and the parts that are original are not good". Among the latter may be mentioned a few errors in

grammar, diction, and orthography, one of which seems to disclose the author's unfamiliarity with the traditional Negro jungle.

"Juba dis and Juba dat
Juba killed de yaller cat
For to make he wife a Sunday hat,
Juba!"

The subtitle of the work is "A Gift Book". Is this meant to imply that no one will be likely to buy it, and it must therefore be given away? The book is provided with an extensive index. One wonders why.

ADVENTURES WITH A MICROSCOPE.

By Richard Headstrom. Frederick A Stokes Company, New York and Toronto. $2.00. 8⅓ x 5½; xxiv + 232; 1941.

The talents of a keen naturalist and successful teacher have gone into the preparation of this fascinating little volume. Although the work is intended primarily for popular consumption among boys and girls of high school age who possess more than a casual interest in the wonders of nature about them, it will undoubtedly find a welcome place on many school reference shelves, and in the hands of leaders of numerous science clubs and nature study groups.

The introduction to the text is a detailed discussion of the structure, use and care of the microscope. Armed thus with the scientist's most powerful weapon, Headstrom leads his readers through some 59 adventures in the microscopic world about us. From one-eyed monsters to bees and bears, mold and worms, roots and silk, the amateur investigator views the proverbial "wonderland". The author's clear and concise directions for collecting and preparing materials for microscopic study, his artistic drawings, and his completely accurate discussions on natural history contribute alike to the excellence of the work. Within these pages, many a boy and girl will undoubtedly hit upon something that will be both a challenge and an inspiration to a life-long interest in nature study.

THE AMERICAN ILLUSTRATED MEDICAL DICTIONARY. *A Complete Dictionary of the Terms Used in Medicine, Surgery, Dentistry, Pharmacy, Chemistry, Nursing, Veterinary Science, Biology, Medical Biography, etc., with the Pronunciation, Derivation, and Definition. Nineteenth Edition.*

By W. A. Newman Dorland with the Collaboration of E. C. L. Miller. W. B. Saunders Company, Philadelphia and London. $7.00, plain; $7.50, thumb-indexed. 9 x 6; 1647; 1941.

An important volume for the reference shelves of all biological laboratories no matter in what special fields the work may lie. The dictionary first appeared in 1900. Within the last fifteen years it has been increased in size by 300 pages, while in the present edition—the nineteenth—there have been added more than 2,000 words. Many of these new words, of course, come from the rapidly developing science of biochemistry, of nutrition, and allied subjects, but the general biologist will find that his own field has not been neglected.

THE MICROSCOPE. *Seventeenth Edition: Revised.*

By Simon Henry Gage. Comstock Publishing Company, Ithaca, New York. $4.00. 9 x 6; viii + 617; 1941.

The two previous editions of this classic have already been reviewed in these columns (Vol. 7, p. 348 and Vol. 12, p. 94). The present edition has been expanded and clarified. It is not only a textbook of microscopic technique, but it makes very interesting reading. It contains new chapters dealing with the preparation of objects and one with the history of microscopy. But the great bulk of the work is concerned with the science of optics. It is of course possible to use a microscope without understanding all of the optical principles involved, but the student who does understand them will certainly derive more pleasure and satisfaction from his work, even if indeed he does not accomplish better results.

The index covers 19 pages and the bibliography 15 pages.

THE MIDDLE WEST. *An Approach to Learning and Living through Examination of the Student's Own Environment. A Syllabus.*

By a Committee of the Faculty of Knox College. John S. Swift Company, Chicago. $3.00 net. 11 x 8½; 1940.

This is a syllabus, with ample space for students' notes, of a full-year course of study conducted by a committee of the faculty of Knox College. The subjects covered include the geology, history, literature, economic structure, sociology, political institutions, education, religion, art, architecture, and music of the region. Reading and essay assignments for the Freshman English course were arranged to fit in with this course and are incorporated in the outline. It should be useful in providing suggestions to school and college administrators and teachers who are interested in introducing a "local interest" course in their schools.

HOW MIRACLES ABOUND.

By Bertha Stevens. The John Day Company, New York. $2.50. 8½ x 6; 200: 1941.

This work is for the purpose of teaching teachers to teach. Each one of its ten chapters is devoted to the discussion of a commonplace object, and of certain of its features which are mostly not familiar. This material is arranged in a way designed to interest children, to excite their curiosity, and to make them observant of nature and appreciative of her beauty. The book is well illustrated with both line drawings and photographs, and has numerous quotations from good poetry to increase its aesthetic appeal.